A STUDY ON VARIATIONS IN THE BRANCHING PATTERN OF ANTERIOR CEREBRAL ARTERY

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CERTIFICATE

Certified that the dissertation on **“A STUDY ON VARIATIONS IN THE BRANCHING PATTERN OF ANTERIOR CEREBRAL ARTERY”** submitted by **Dr.J.Sujitha Jacinth,** postgraduate student, Institute of Anatomy, Madurai Medical College, Madurai, submitted to The Tamilnadu Dr. MGR Medical University, Chennai, in partial fulfillment of the requirement for the award of M.S Degree in Anatomy, is a bonafide work carried out by her under my direct supervision and guidance.

Place: Madurai
Date:

Director & Professor
Institute of Anatomy
Madurai Medical College
Madurai.

DECLARATION

I, **Dr.J.Sujitha Jacinth** solemnly declare that the dissertation on **"A STUDY ON VARIATIONS IN THE BRANCHING PATTERN OF ANTERIOR CEREBRAL ARTERY"** has been prepared by me under the precious guidance and supervision of **Professor Dr.V.Rajaram, M.S**, Director I/C, Institute of Anatomy, Madurai Medical college, Madurai. This work is submitted as partial fulfillment of the requirement for the award of **M.S (Anatomy)** Degree Examination of **The Tamilnadu Dr. M.G.R Medical University, Chennai** to be held in September 2008. This work has not formed the basis for the award of any other Degree or Diploma from any other university.

Place: Madurai **J. SUJITHA JACINTH**

Date:

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CONTENTS

INTRODUCTION

Science and Technology is growing fast day by day both in developing and developed countries. With the advent of these changes, one could observe diverse patterns of life in accordance with the improvement in modern techniques. Nowadays cerebrovascular catastrophes have become a common occurrence, irrespective of the type of job the people are doing. Modern techniques and advanced treatment are there by which the survival rate and recovery could be achieved. Even then there is recovery with some residual disabilities and for some it is fatal. A World Health Organization collaborative study in 12 countries showed that the stroke incidence ranged from 0.2-2.5 per 1000 population per year. In India out of 9.4 million, 61900 deaths were due to stroke. This gives a stroke mortality rate of 73 per one lakh. Cerebral thrombosis is usually the most frequent form of stroke encountered in clinical studies.

The diagnostic procedures have provided new insights into risk factors for thrombotic and embolic ischemic stroke. Magnetic resonance imaging has become the preferred technique of brain imaging because of the wealth of information it offers. Depending upon the location and distribution of the lesion, the presentation of the clinical condition varies. So a thorough knowledge of the branching pattern and area of distribution is of prime importance in diagnosing the clinical condition.

The anatomy of the branches of the anterior cerebral artery and the anterior communicating artery complex needs to be investigated individually to minimize neurovascular morbidity prior to iatrogenic procedures. With the advances in micro- neurosurgery and the ability to tackle diseases of the intracranial arteries more effectively, accurate knowledge of the intra cranial vascular anatomy is increasingly important. Knowledge of the normal size of the vessels may also be of use to the surgeon in assessing the feasibility of shunt operations.

This study presents variation in the dimensions and the branching pattern of anterior cerebral artery in 50 specimens by an attempt to establish a norm with an expectation that it will hopefully contribute to better interpretation of diagnostic studies for better management.

AIM AND OBJECTIVES

- To study the dissimilarity in branching pattern of anterior cerebral arteries.
- To generate an idea about the normal dimensions of the vessels that may contribute greatly to surgeon’s assessment on the feasibility of shunt operations.
- To study the discrepancy in the anatomy of the anterior cerebral artery so that this may partially explain differences in the incidence of some of the cerebrovascular diseases.
- To study the relevant anatomy to understand the accurate account of the vascular variation which are of neurosurgical importance during exposure of regions for different surgical purposes.
- Comparing the observed results with previous autopsy studies.

REVIEW OF LITERATURE

Thomas Willis (1664) first described the circle of Willis and its physiological significance in his paper on “Cerebri Anatome”.

Heubner (1874) identified an artery arising either at the level or just proximal or distal to the anterior communicating artery named as recurrent artery of Heubner, which was one of the medial striate arteries.

Wilder (1885) coined the term “Arteria Termatica” to describe the fusion of both A2 segments to be present as a single artery.

Windle (1887) on his observations on the arteries forming the circle of Willis suggested that the blood supply to the left half of the brain was on the whole less complete than that to the right half. He also reported an unpaired or azygos anterior cerebral artery arising by proximal union of the anterior cerebral arteries on both sides, without an anterior communicating artery was found to be less than 5% of the adult brains.

Fawcett E (1905) made a study of the circle of Willis with a view to find out how often it was complete and incomplete. It was observed that the circle was often complete. If incomplete, it would be due to an absence of either one or both posterior communicating, or anterior communicating arteries. Asymmetrical variations were attributed to the absence of a posterior communicating artery or doubling of an anterior cerebral artery on one side. He observed a third anterior cerebral artery arising from the anterior communicating artery. The incidence of the third anterior cerebral artery was more in males than in females.

Beevor CE (1907) described the cerebral arterial supply and subdivided the distal segments into A2, A3, A4 and A5 segments. The A2, A3 segments have together been referred to as the ascending segments and A4, A5 as horizontal segments.

Aitken HF (1909) studied the course of recurrent artery, which was running caudally and laterally, giving rise to significant branches prior to its entry into the anterior perforated substance. This artery supplies the anteromedial part of the head of the caudate nucleus, adjacent parts of the internal capsule and putamen.

Padget DH (1948) studied the development of the cranial arteries in the human embryo. He noticed that the anterior cerebral artery was arising as an offshoot from the primitive olfactory artery, eventually becoming the dominant vessel. He reported that the recurrent artery of Heubner was a remnant of the primitive olfactory artery.

Kaplan HA (1958) has reported the existence of an anastomosis between the recurrent artery of Heubner and the lenticulo striate arteries. He also reported anastomosis between recurrent artery of Heubner and surface branches of middle cerebral artery. He has also demonstrated the arterial supply to the inferior surface of the frontal lobe to be by several branches from the recurrent artery of Heubner.

Alpers BJ et al (1959) described the branching pattern of the circle of Willis. After studying brains of 381 humans, anomalies of distal part of anterior cerebral arteries were present in 25% which included pericallosal artery triplication, pairing of anterior cerebral artery and bihemispheric branching from the anterior cerebral arteries.

Ostrowski AZ et al (1960) observed that in 78%, the origin of recurrent artery of Heubner was from the distal part of anterior cerebral artery, 14% from the proximal part of anterior cerebral artery and on the remaining 8% at the level of the anterior communicating artery. He has also reported the arterial supply of the paracentral lobule and parts of the cingulate gyrus from the branches of the callosomarginal artery.

Baptista AG (1963) classified the varying patterns of the anterior cerebral arteries. According to him, pattern I was its common pattern of branching, pattern II if associated with an accessory anterior cerebral artery, pattern III if there was an ayzgos trunk and pattern IV if with bihemispheric distribution of cortical branches.

Riggs HE et al (1963) studied the cross sectional differences in the vessels of circle of Willis. In this study 1.5 mm was taken as the standard diameter. They reported that 7% had hypoplasia in the A1 segment of anterior cerebral artery and 6% hypoplasia in the anterior communicating artery. They also reported a high frequency of saccular aneurysms associated with the above anomalies.

Stebbens WE (1963) studied the anatomical variations of cerebral arteries and aneurysms. He brought forth the association between A1 segment hypoplasia and saccular aneurysms. He showed that cardiac embolism caused occlusion of anterior cerebral artery with hypoplasia.

Fisher CM (1965) on his study on circle of Willis, divided the anterior cerebral artery as proximal or A1 segment, that is from its origin up to its junction with the anterior communicating artery and distal or A2 segment, that is the part of the artery distal to its communication with the anterior communicating artery.

Lemay M et al (1966) studied the clinical significance of an unpaired or azygos anterior cerebral artery. They found an anomalous union of the proximal parts of the anterior cerebral arteries, where there was no anterior communicating artery. This anomalous artery later bifurcated and an aneurysm had been reported at the site of bifurcation.

Ahmed DS et al (1967) demonstrated the origin of recurrent branch of the anterior cerebral artery. In different series it arose most often from the A1 segment. They have also demonstrated the origin either from A2 segment or at the level of the anterior communicating artery. Absence or doubling has occurred. The recurrent artery of Heubner rarely arises from the internal carotid artery at its bifurcation or from the middle cerebral artery.

Stephens RD et al (1969) made a study in 50 adult autopsy specimens and observed that 60% had one communicating artery, 30% it was double and in the rest 10% it was triple. They had reported A1 segment duplication and a third or median anterior cerebral artery from the anterior communicating artery, which was as large as the two other anterior cerebral arteries.

Salamon G et al (1971) described a pericallosal artery as the terminal branch of the anterior cerebral artery, which ran along the dorsal surface of the corpus callosum and supplied the medial surface of the parietal lobe including the precuneus.

Raja Reddy et al (1972) have reported the hypoplasia of vessels to be the commonest anomaly in the circle of Willis. They also observed abnormal diameter of the human, the incidence of which was more or less in the posterior communicating artery followed by anterior cerebral artery.

Szdzuy D etal (1972) observed a long common trunk of the anterior cerebral artery together with agenesis of corpus callosum and meningocoeles.

Warwick et al (1973) recognized that the composite vessels of the circle contain a greater length and a smaller diameter in the right half of the circle. Hence blood flow would be better in the left half since the volume of blood flow through a vessel is inversely related to the length of the vessel and directly related to its diameter. This fact explains the dominance of the left hemisphere and the common occurrence of right-handedness in human.

Belenkaya RM (1974) studied the structural variants of the arteries at the brain and observed that the azygos pericallosal artery was rather common in lower primates, but was seen in 0.2-3.7% of humans. That was the reason to refer this anomaly as a monkey type of anterior cerebral artery.

Perlmuter D et al (1976) studied the micro-surgical anatomy of the anterior cerebral-anterior communicating-recurrent artery complex. They observed that there was a direct correlation between the differences in diameter between A1 segments of either side and the diameter of anterior communicating artery. The greater the difference in diameter between the two A1 segments, larger the diameter of the anterior communicating artery. They also observed the origin of the recurrent artery of Heubner from the A2 segment in 78%, A1 segment in 14% and anterior communicating artery in 8%.

Puchabus-orts et al (1976) showed angiographic evidence of agenesis and hypoplasia of the initial segment of the anterior cerebral artery and anterior communicating arteries.

Bosma NJ (1977) studied an infraoptic course of anterior cerebral artery from the internal carotid artery and established the fact that the anomalous vessel itself could cause visual symptoms due to compression of the optic nerve or optic chiasma. The infra optic anterior cerebral artery had been considered as a remnant of the embryonic primitive maxillary artery.

Brismar J et al (1977) studied the anomalies of anterior cerebral artery and reported that the A1 segment hypoplasia was bilateral and associated with saccular aneurysm, duplicated middle cerebral artery, median corpus callosum artery, aortic coarcation or cerebral lipoma.

Crowell et al (1977) reported that the anterior communicating artery had significant branches and its penetrating branch was found to be less than or equal to 13 in number. They also recognized the fact that the branches supplied the area associated with suprachiasmatic paraolfactory, dorsal optic chiasma, anterior perforated substance, inferior frontal lobe, septum pellucidum and corpus callosum.

Ozaki et al (1977) studied the anatomical variations of the arterial system of the base of the brain. They reported an azygos or undivided anterior cerebral artery dividing into two pericallosal artery and two callosomarginal arteries at variable distances from its origin distal to the genu of corpus callosum.

Perlmuter D et al (1978) distinguished the distal anterior communicating artery and subdivided into four segments, with the A2 segment beginning at the anterior communicating artery and ending at the junction of the rostrum and genu of the corpus callosum, the A3 segment extending from the genu of the corpus callosum and ending at the site where the artery turned sharply above the genu. A4 and A5 segments were located on the corpus callosum and divided into anterior (A4) and posterior (A5) portions by an imaginary line just posterior to the coronal suture.

Lazorthes A et al (1979) reported the course of pericallosal artery. They regarded it as the terminal branch of the anterior cerebral artery which ran along the dorsal surface of the corpus callosum and supplied the medial surface of the parietal lobe including the precuneus.

Ito J et al (1981) reported a case of fenestration on the right anterior cerebral artery associated with ruptured aneurysm with contra lateral A1 hypoplasia.

Milenkovic Z (1981) examined the asymmetry and anomalies of the circle of Willis in fetal brain and attributed them to the defects in kinetic factors. He observed that genetic factors are probably responsible not only for the development of the circle but also for caliber. The difference in arterial calibers of the cerebral arterial circle during life could be the results of hemodynamic stress or compression of the afferent vessels.

Sylvia Kamath (1981) studied the length and diameter of vessels forming the circle of Willis and observed that the coefficient of variation on length was greatest for the anterior communicating artery and that for diameter was greatest for the posterior communicating artery. Abnormal narrowing of vessels was a common occurrence on the right side than on the left relating the need for a better blood supply to the left hemisphere.

Rosner SS et al (1984) studied the micro surgical anatomy of the perforators arising from the surface of the anterior communicating artery. They reported that in 90% of the cases the perforators supplied the pre optic area of the hypothalamus. An average of four perforating branches arose from the A2 segment to supply the anterior fore brain below the corpus callosum.

Henry JM Barnett (1986) reported that the obstruction of both anterior cerebral arteries clinically manifested with bilateral paralysis especially of lower limbs and associated with impaired sensation that mimics a spinal cord lesion.

Hillen B (1987) made an analysis of 100 adults which indicated that variations in the circle of Willis was based on a delicate hemodynamic "tuning" of all segments and that the relations between diameters of segments exist without reference to flow changes in the afferent arteries during movement of the neck.

Senir et al (1987) demonstrated the presence of perforating branches from the anterior communicating artery. These branches were traced to the region of the infundibulum and hypothalamus where they penetrated the brain substance to supply the preoptic area of the hypothalamus.

Brust JCM (1989) on the study of anterior cerebral artery disease established that bilateral medial prefrontal damage results in motor and psychomotor abnormalities, bradykinesia, rigidity and abulia. These were due to the obstruction of anterior cerebral artery.

Marinkovic et al (1989) reported a short azygos trunk bifurcated at the level of genu and a long trunk running almost the entire length of corpus callosum. The report also mentioned that the diameter of the pericallosal artery was greater than that of A1 segment.

Radomir R. Vucetic (1998) described the segmental duplications of the fetal anterior cerebral artery. The occurrence was studied in 200 fetuses of 20-40 weeks of gestational age. Duplications were found in 21 of the 200 fetuses. These duplications were located in the distal part of the A1 segment in 45.7%, at the level of the anterior communicating artery (A1-A2) in 37.7%, and in the initial part of the A2 segment in 16.6%. The duplications had 4 different forms namely oviform, fissured, triangular and punctate.

Miyazawa et al (2000) published small series of distal anterior cerebral artery aneurysm associated with azygos pericallosal artery. Statistical analysis of factors affecting the outcome of patients with ruptured distal anterior cerebral artery aneurysm was examined. They observed that clinical importance of the azygos pericallosal artery depended on thromboembolic complications and surgical approach to anterior cerebral artery aneurysms.

Emel AVCI et al (2003) carried out an anatomic study of the branches of the anterior cerebral artery near anterior communicating artery complex. They identified that the recurrent artery of Heubner, orbitofrontal artery and frontopolar artery were the branches of the anterior cerebral artery which originated near the complex in all the hemispheres. Orbitofrontal artery always originates from the A2 segment and was consistently the smallest branch and coursed to the gyrus rectus and olfactory tract.

Satoshi Ihara et al (2003) reported the aneurysm and fenestration of azygos anterior cerebral artery. The fenestration was seen in the A1 segment and the aneurysm was at the proximal end of the fenestration at the origin of a perforating artery.

Esra Gurdal et al (2004) observed the two variations of the anterior communicating artery. In the first case it was a duplicated anterior communicating artery with fenestrated anterior cerebral artery. In the second case, it was an oblique anterior communicating artery running across and joining in the right side of anterior cerebral artery.

Paul S et al (2004) made a dissection study on variations of the anterior cerebral artery in human cadavers in 50 specimens. In these studies 9 of them showed an aberrant course and anastomosis between the anterior cerebral arteries of both the hemispheres. Most of the anastomoses were seen on the orbital surface of the frontal lobe. Arteries on both sides showed differences in their size also.

SB Pai et al (2005) described the microsurgical anatomy of the proximal and distal anterior cerebral artery, anterior communicating artery and its branches. The origin, branches, outer diameter, length and anomalies of the A1, anterior communicating artery and A2 segment were documented. The variations in the study were found to be more in the anterior communicating artery and distal anterior cerebral artery segments rather than the A1 segment.

Nicole S.Burbank et al (2005) presented the case of an anomalous origin of the left anterior cerebral artery from the supraclinoid segment of the right internal carotid artery. Because of improved imaging quality, anomalies of the anterior cerebral artery and anterior communicating artery complex are increasingly recognized on transaxial images. Recognition of these anomalies may be instrumental in developing a different diagnosis or for improved surgical planning.

Behzad Eftekhar et al (2006) observed the distribution of variations of circle of Willis in different population. No definite variations of cerebral arterial circle were noted.

Vasovic LP (2006) made a comparative morphological variations and abnormalities of circles of Willis and believed that the arterial variations and abnormalities had fetal characteristics and that they were the result of a genetically established pattern. They suggested that the arterial variations and abnormalities could also preserve their relationships because of constant interaction between primitive arterial remnants and brain arteries in postnatal life.

MATERIAL AND METHODS

Fifty brain specimens were collected from the embalmed cadavers in the Institute of Anatomy and also from the autopsy specimens in the Department of Forensic Medicine, Madurai Medical College, Madurai.

The present study was carried out irrespective of age, sex and socio economic status. The specimens were collected from the subjects who had died of natural or traumatic causes. Those cases with remarkable alterations of the brain or evidencing gross pathological lesions like crushed injuries, macroscopically identified cortical tumors, severe hemorrhages or infections were excluded. A coronal incision was made in the scalp, which started from the mastoid process and was carried over the vertex of the scalp to the back of the opposite ear. The incision extended deeply up to the periosteum. The scalp flaps were reflected to the superciliary ridges in front and backwards to a point below to the occipital protuberance. The frontal eminence, two parietal eminence and external occipital protuberance were marked. The temporal and masseter muscles were cut on either side for sawing the skull. The saw-line was marked in slightly V-shaped direction which passed through the bones along a line extending horizontally on both sides, from about the center of the forehead to the base of the mastoid process and from this later point backwards and upwards to a point a little above the external protuberance. The vault of the skull was sawed with a hacksaw blade along the saw line and removed.

A small knick was made in the duramater on either side of the mid line. The duramater was grasped anteriorly with a toothed forceps and scissors and divided from before backwards into two halves. Another cut along the plane of coronal suture was made and divided into four flaps. The attachment of falx cerebri from cribriform plate was cut and pulled posteriorly. The attachments of the cranial nerves were cut on both the sides. The tentorium cerebelli was also cut along the posterior border of the petrous bone and the brain was supported by the left hand. A knife was passed into occipital foramen and cervical cord, first cervical nerves and cerebral arteries cut as far below as possible and the brain was removed from cranial cavity. The specimens were preserved in 10% formalin solution and numbered serially from 1 to 50 for the study.

The inferior surface of the brain was viewed and the internal carotid artery was identified. The origin of anterior cerebral artery from the internal carotid artery and the anterior communicating artery uniting the two anterior cerebral arteries were traced. Here the anterior cerebral artery lies below the anterior perforated substance, lateral to the optic chiasma. From here it runs forwards and medially crossing above the optic nerve to reach the longitudinal fissure separating the two cerebral hemispheres. The two hemispheres were separated at the longitudinal fissure by a midline incision through the corpus callosum and allowed to fall apart to view the medial surface. Further course of the anterior cerebral artery in front of the genu and above the body of the corpus callosum and ending near its posterior part were identified.

The site and origin of the anterior cerebral artery was noted. The length and the external diameter of the A1 segment and anterior communicating artery were measured. A caliper graduated to measure up to 0.1mm was used for the measurement of diameter. The origin of the Heubner's artery, Perforators, orbitofrontal, frontopolar, callosomarginal artery, pericallosal artery, medial rolandic artery and its encroachment to superior border and supero lateral surface, medial prerolandic artery, and posterior parietal arteries were studied. The presence of azygos anterior cerebral arteries, fenestration and aneurysm were looked for. Photographs were taken almost perpendicular to the plane of the arteries in order to avoid errors due to different angles of view. The variations of the anterior cerebral artery were compared with the previous studies.

Instruments and other accessories used

- Stainless steel student's scalpel.
- Stainless steel long and short forceps- toothed and non- toothed.
- Stainless steel straight scissors.
- Electric saw and Brain knife
- Vernier caliper.
- Black cream sheet, Graduated scale, protractor, HB pencil, 0.4mm thread and Cotton.
- Gloves and Apron
- Covered container for preserving specimens in formalin.

OBSERVATION

I. External diameter of internal carotid artery at its termination

The outer diameter of the internal carotid artery on both sides was in the range of 3.5mm to 5mm with a mean of 4.33mm on right and 4.45mm on left side. Percentage variation with respect to the external diameter of internal carotid artery at its termination is shown in Fig: 20.

Table: 1

External diameter (mm)	Right (nos)	Left (nos)
3.5 – 4	9	9
4.1 – 4.5	24	24
4.6 – 5	17	17

II. External diameter of middle cerebral artery at its origin

The outer diameter of the middle cerebral artery on both sides was in the range of 3.5mm to 4.5mm with a mean of 3.41mm on right and 3.52 mm on left side. Fig: 21 represent the percentage disparity with regard to the external diameter of middle cerebral artery at its origin.

Table: 2

External diameter (mm)	Right (nos)	Left (nos)
3 – 3.5	36	36
3.5 – 4	9	9
4 – 4.5	5	5

III. Anterior cerebral artery

a) Origin of Anterior cerebral artery

In all the 50 specimens (Fig: 1) dissected the anterior cerebral artery was branching from the corresponding internal carotid artery.

Table: 3

Name of the artery	Nos.
Internal carotid artery	50
Others	0
Total	50

b) Origin of anterior cerebral artery

On both sides only one anterior cerebral artery was seen from each internal carotid artery at the anterior perforated substance. The internal carotid artery was divided into the anterior cerebral artery and the middle cerebral artery at the level of anterior perforated substance (Fig: 2). The anterior cerebral artery coursed anteromedially to cross over the optic nerve and the optic chiasma to communicate with opposite anterior cerebral artery through the anterior communicating artery. This segment from origin to the anterior communicating artery was considered as A1 segment in the study.

c) Length of A1 segment

The length of the A1 segment was in the range of 11mm to 17mm with a mean length of 14.8mm on right and 14.7 mm on the left side. Of all the specimens studied, it has been noticed that the length of the A1 segment ranged from 11 to12mm in two specimens on right (Specimen No: 12 &18) and one on the left side (Specimen No: 12). Only one specimen on right side had length with a range of 12 to 13mm (Specimen No: 36). Thirty one specimens on the right side and thirty two on the left side had a length ranging from 14 to 15 mm. Fourteen specimens on both sides had a length of range 15 to16 mm. The remaining two specimens on right side (Specimen No: 22, 34) and three on left side (Specimen No: 12, 13, 34) had a length with a range of 16 to17 mm. The difference in length between two sides was in the range of 0.1to 0.2 mm which was exactly same except in Specimen No: 12 where there was a difference of 4.9 mm. In Specimen No: 13 there was a difference of 2.8 mm and in Specimen No: 22 & 36 there was a difference of 0.9 mm. It has been noticed that most of the specimens had a length of A1 segment with a range from 14–15mm as shown in Fig: 22.

Table: 4

Length (mm)	Right (nos)	Left (nos)
11-12	2	1
12 – 13	1	0
13 – 14	0	0
14 – 15	31	32
15 – 16	14	14
16 – 17	2	3

d) Outer diameter of A1 segment at its origin

The outer diameter of the anterior cerebral artery on both sides was ranging from 1.5 to 3.2mm with a mean of 2.51mm on the right and 2.6mm on the left side. In two specimens the diameter of right anterior cerebral artery was above 3 (Specimen No 12 & 23) which was larger on the right side with a difference of 0.9mm (Specimen No: 12) and 0.5 mm

(Specimen No: 23). The diameter of the anterior cerebral artery was larger on the left side in eighteen cases, larger on right side in three cases and was of equal diameter on both sides in twenty nine cases. In only one case (Specimen No: 36) there was a difference of 1mm diameter between the two anterior cerebral arteries but in no situation was the difference larger than 1mm. Fig: 23 correspond to the percentage discrepancy of the outer diameter of A1 segment at its origin.

Table: 5

External Diameter (mm)	**Right (nos)**	**Left (nos)**
1.5 – 2	1	1
2.1 – 2.5	24	24
2.6 – 3	23	27
> 3	2	-

e) Angulations of A1 segment

On its course towards the anterior communicating artery, the anterior cerebral artery took an anteromedial course at an angulation varying from 50^0 to 60^0 to the anteroposterior plane. There was no difference in angulation between the two sides. Angulations of A1 segment towards percentage variation is shown in Fig: 24.

Table: 6

Angle (degree)	Right (nos)	Left (nos)
50	15	15
55	27	27
60	8	8

f) Branches from A1 segment- perforators

It has been noted that these perforators arose from the postero inferior and postero superior surface of A1 segments of the anterior cerebral artery (Fig: 7). These were generally very small twigs and few in number and situated more medially than laterally. On the right side fifteen specimens had one perforator, twenty five had two perforators. On the left side sixteen had one perforator, twenty six had two perforators. Three perforators arose in eight specimens on both the sides and also a maximum of four perforators took origin in two specimens only on the right side. Fig: 25 represent the percentage variation in number of perforators from the A1 segment.

Table: 7

No of perforators	Right (nos)	Left (nos)
1	15	16
2	25	26
3	8	8
4	2	0

IV. Anterior communicating artery

In all the specimens, except in one the anterior communicating artery was found above the optic chiasma. It was horizontally located in all the forty-nine cases. In four cases there was a duplication of the anterior communicating artery (Fig: 6)/(Specimen No: 4, 32, 45 & 48) with formation of loop in one specimen (Fig: 8)/(Specimen No: 32). In Specimen No: 40 there was an absence of anterior communicating artery with fusion of two A1 segments which ended by dividing into two A2 segments (Fig: 9).

a) **Length of Anterior communicating artery**

The length of the anterior communicating artery varied from 1.5mm to 4mm with a mean of 2.6mm. In Specimen No: 4 & 48 the length of the second anterior communicating artery was equal to the first one. In the Specimen No: 32 the second anterior communicating artery joining the two A2 segment was about 3mm from the first. In Specimen No: 45 the second anterior communicating artery was thin and small. Fig: 26 illustrate the percentage discrepancy in length of the anterior communicating artery.

Table: 8

Length (mm)	**Nos.**
1.5 – 2	2
2.1 – 2.5	14
2.6 – 3	29
3.1 – 3.5	2
3.6 - 4	2

b) External diameter of Anterior communicating artery

The external diameter of the anterior communicating artery was in the range of 1mm to 3mm with a mean of 2mm.The diameter of the artery was less than the length in 41 cases, equal to the length in remaining eight cases. Out of the four duplicated arteries three had the same diameter. The fourth duplicated artery had a diameter of just 1mm. Fig: 27 represent the percentage variation in external diameter of the anterior communicating artery.

Table: 9

External diameter (mm)	Nos.
1 – 1.5	6
1.6 - 2	23
2.1 -2.5	17
2.6 - 3	3

c) Anterior communicating artery perforators

All the 49 anterior communicating arteries gave rise to perforators which ranged from 1 to 3 in number. They arose from the posterosuperior surface of the artery and coursed superiorly as thin small vessels (Fig: 7). The percentage variation in number of perforators of the anterior communicating artery is shown in Fig: 28.

Table: 10

No. of perforators	No. of Anterior communicating artery
1	19
2	24
3	6

V. The Recurrent artery of Heubner

The recurrent artery of Heubner was seen to arose at the level of junction of anterior cerebral artery and anterior communicating artery in four cases (Fig: 10), proximal to the junction in five cases, and distal to the junction in 40 cases on both sides (Fig: 11). The percentage difference in the site of origin of the recurrent artery of Heubner is shown in Fig: 29.

Table: 11

Site of origin	Right (nos)	Left (nos)
Proximal to ACoA	5	5
At the level of ACoA	4	4
Distal to the ACoA	40	40

VI. Distal anterior cerebral artery or A2 segment

a) Diameter of the distal anterior cerebral artery

The portion of the anterior cerebral artery distal to the anterior communicating artery is referred to as the distal anterior cerebral artery or A2 segment. The A2 diameter was in the range of 2mm to 3.5mm on both sides with a mean of 2.5mm on the right and 2.5mm on left side. In forty seven cases both the A2 segments were of equal diameter and in three cases right A2 was larger. Fig: 30 represent the percentage disparity with regard to external diameter of the distal anterior cerebral artery.

Table: 12

Diameter (mm)	Right (nos)	Left (nos)
2 -2.5	24	29
2.6 - 3	23	21
3.1 – 3.5	3	0

b) Variations in the branching pattern of the A2 segment

The A2 segments hardly gave rise to any perforators apart from the recurrent arteries. The cortical branches that were seen constantly in all specimens were the orbitofrontal (Fig: 5), frontopolar (Fig: 4) and callosomarginal arteries (Fig: 3). The callosomarginal artery was seen to arise at the level of the genu of the corpus callosum in all cases except one in which it arose proximal to the genu. After giving the fronto polar branch it ended by dividing into three branches (Fig: 17). Usually the A2 segment distal to the callosomarginal artery continued as the pericallosal artery which ran posteriorly over the corpus collosum. In one specimen an interhemispheric branch arising from the A2 segment on the right side continued as the pericallosal artery on the left side (Fig: 18). The posterior parietal artery on the left side originated from the crossed pericallosal artery (Fig: 19). The medial rolandic branch was found in thirty cases, medial prerolandic was found in five cases and posterior parietal branches were found in eleven cases.

The A2 segments gave branches to both sides of the hemisphere in four cases (Specimen No: 12, 13, 23 &36). In all these four cases the inter hemispheric branches were given of from right to left side and consequently the diameter of the right A2 segment in these four specimens were larger than the left side.

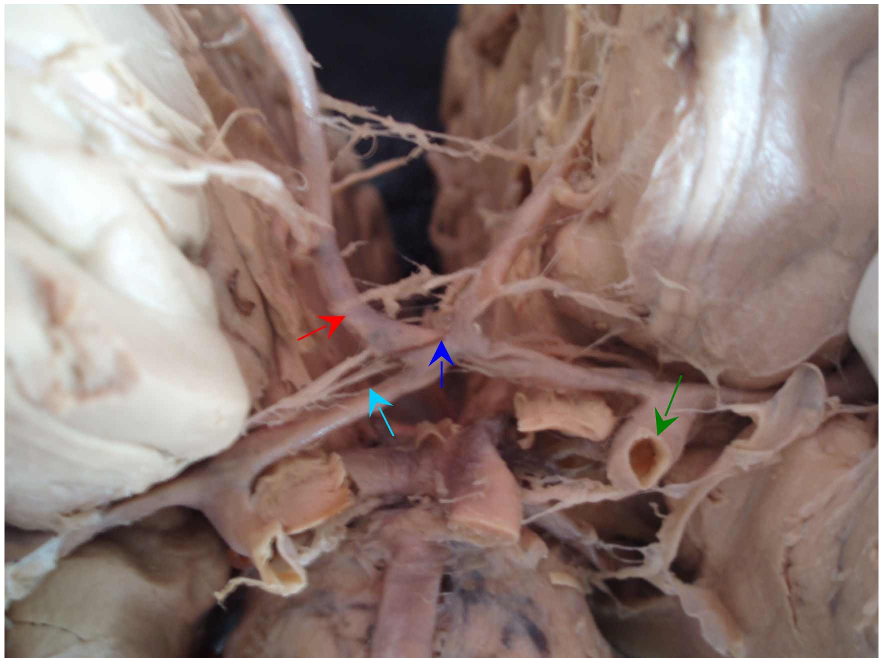
In Specimen No:12 on the right side the frontopolar, callosomarginal, medial rolandic, pericallosal artery were seen in the normal pattern while on the left side the frontopolar and callosomarginal arose from the same side of A2 segment and the pericallosal artery continued from an inter hemispheric branch (Fig: 18).

In Specimen No: 13 the A2 segments from both sides were passing only on the right side above the corpus callosum. One of the A2 segment provided five inter hemispheric branches which crossed to the left side of cerebral hemisphere (Fig: 12). This inter hemispheric branches provided the frontopolar callosomarginal and pericallosal artery on the left side. Again a third branch was arising at the level of anterior communicating artery running upwards along with the other two A2 segments above the genu of the corpus callosum, followed the course in the same manner and ended by turning upwards similar to the callosomarginal artery on the right side (Fig:15 &16).

In Specimen No: 23 the branching pattern on the right side are normal. On the left side only the fronto polar was seen to be coming from the left A2 segment. The remaining branches namely callosomarginal, medial rolandic, posterior parietal and pericallosal arteries arose from an inter-hemispheric branch of the right side. The branches of the A2 segment had an encroachment over the superomedial border to run in the supero lateral surfaces of the cerebral hemispheres (Fig: 13, 14).

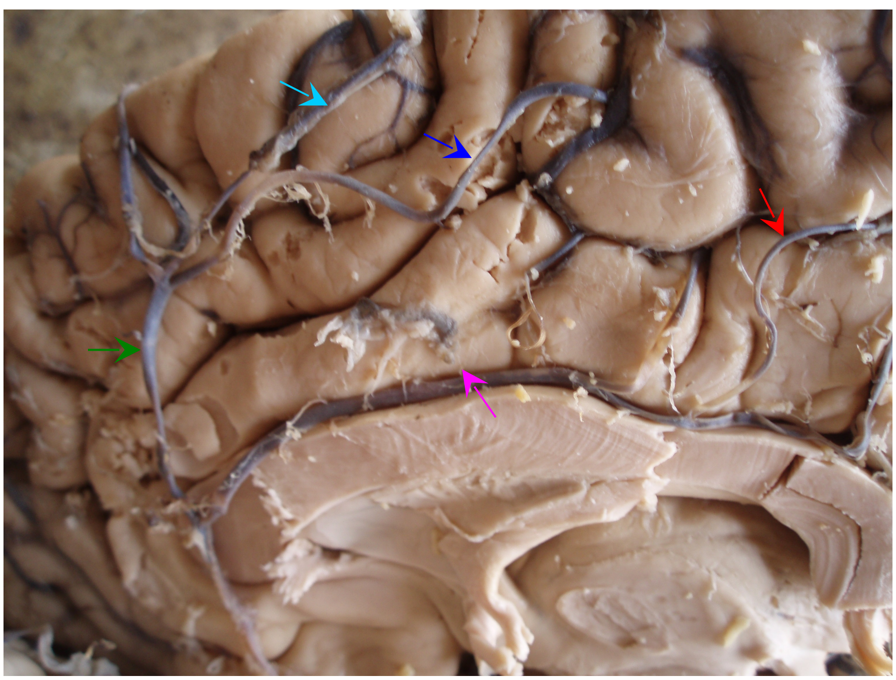
Apart from the present study, angiographic interpretation was made in four cases. Normal pattern of blood vessels were seen in the CT angiogram showing arteries forming the circle of Willis and also in the MR angiogram with coronal view Fig: 31(a, b) and Fig: 33 (a, b). MR angiogram with the axial view Fig: 32 (a, b) shows the absence of anterior cerebral artery on the left side. **This angiographic study was excluded from the data's of the fifty specimens dissected.**

Fig: 1. Fifty brain specimens assembled during the present study



Internal carotid artery
Anterior communicating artery
A1 segment – Anterior cerebral artery
A2 segment

Fig: 2. Origin of anterior cerebral artery and its segments



Callosomarginal artery
Medial rolandic artery
Pericallosal artery
Medial Prerolandic artery
Posterior parietal artery

Fig: 3. View of branches in the A2 segment

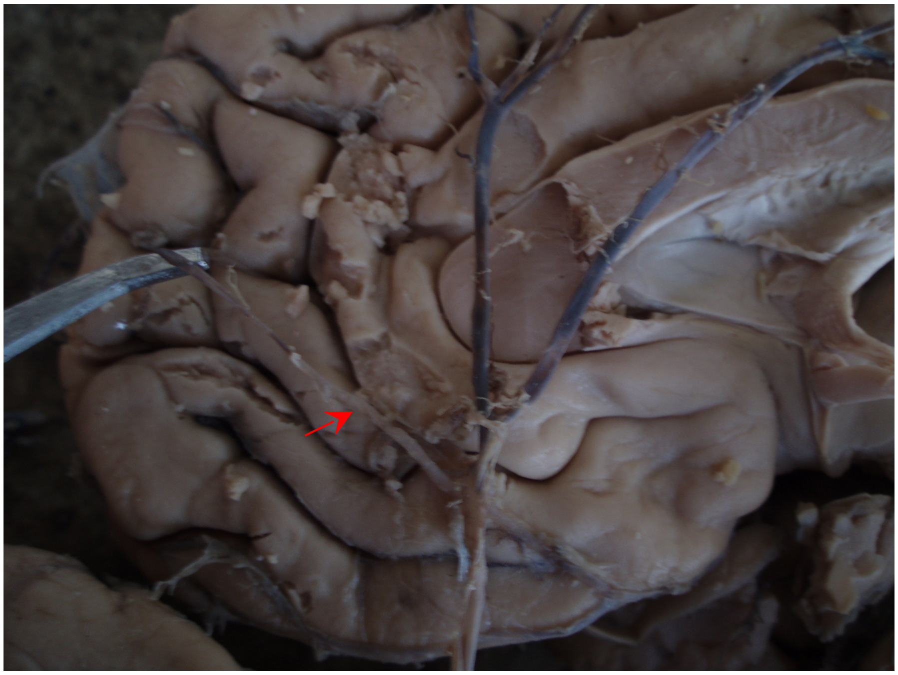


Fig: 4. Image of frontopolar branch in theA2 segment

Fig: 5. Photo representing the appearance of orbitofrontal arteries

Fig: 6. Picture representing the two anterior communicating arteries

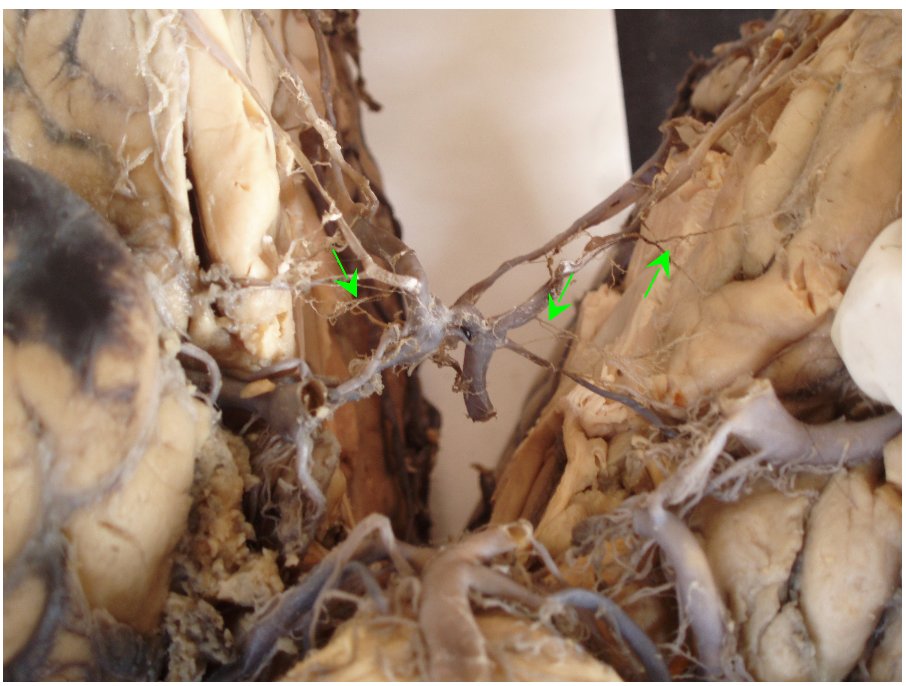


Fig: 7. Outlook on the perforators of A1 segment – Anterior communicating artery complex

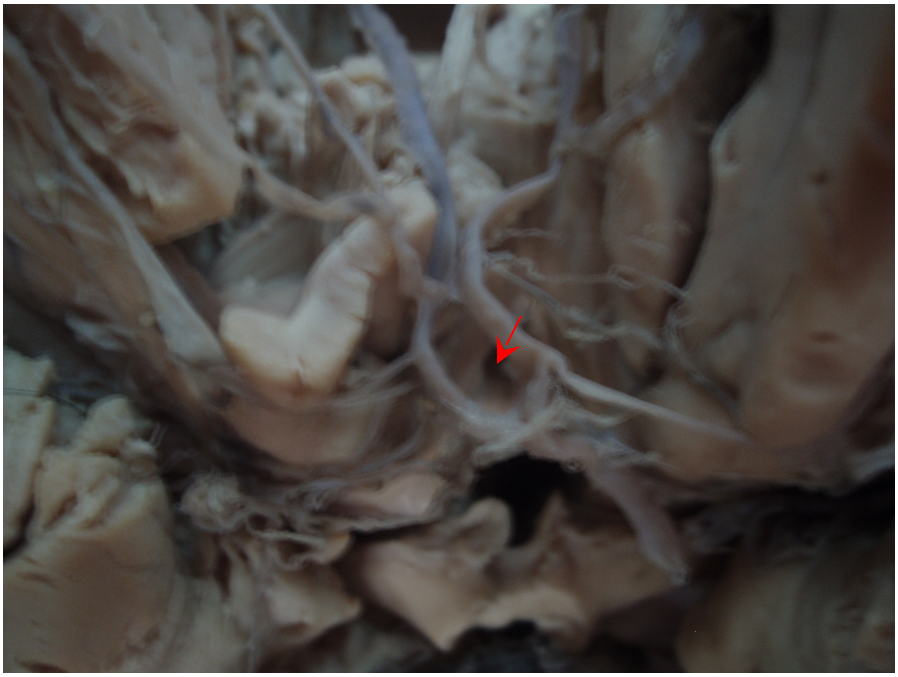


Fig: 8. Visualization of loop formation in the anterior communicating artery

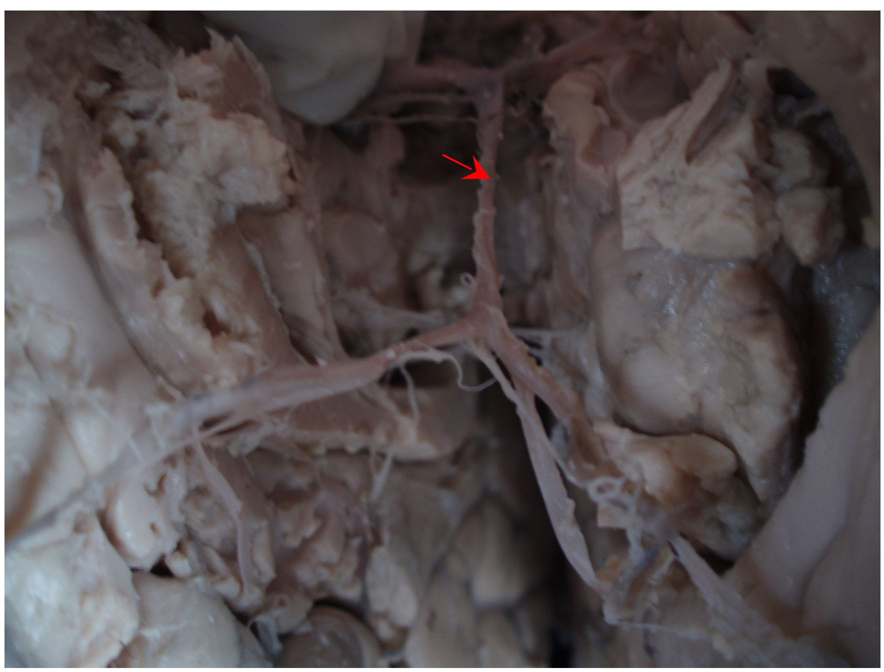


Fig: 9. Image of the absence of anterior communicating artery with fusion of two A1 segments

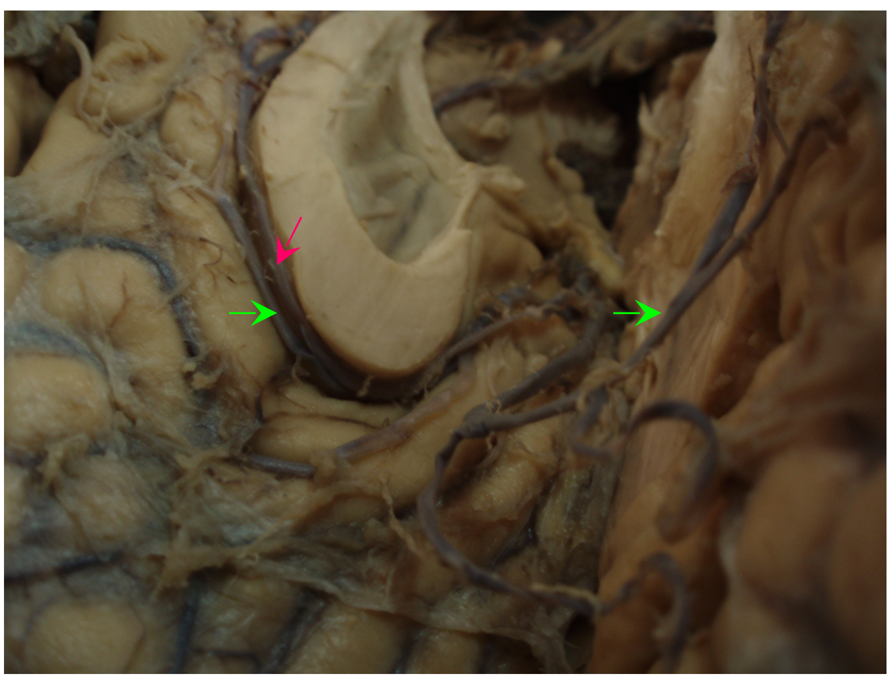
Fig: 10. Image of recurrent artery of Heubner at the level of anterior communicating artery

Fig: 11. Representation of recurrent artery of Heubner distal to anterior communicating artery

Fig: 12. View of five Interhemispheric branches from right to left

Fig: 13. A2 segment branches encroaching with the supero lateral surface

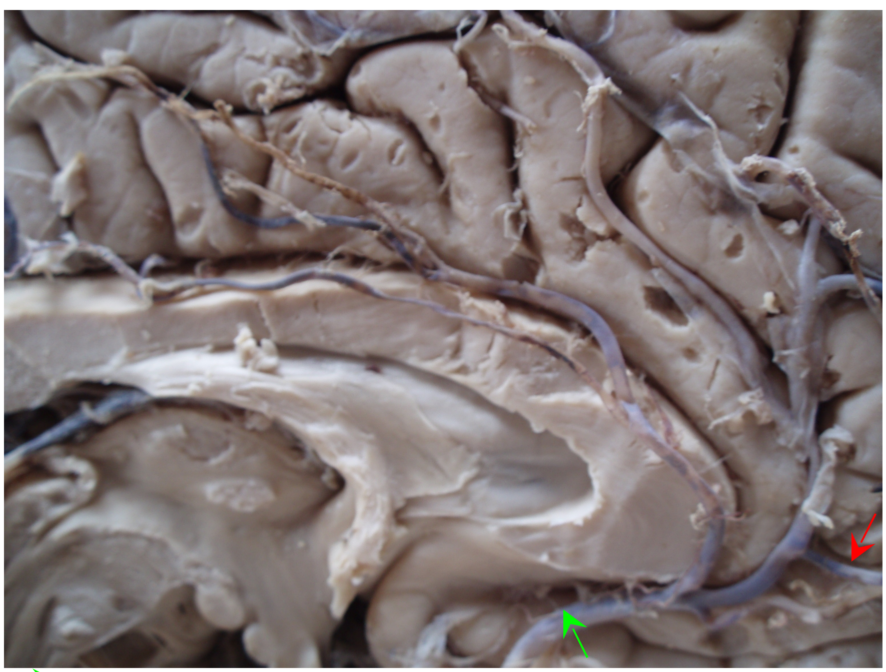
Fig: 14. Callosomarginal and medial rolandic branches encroaching with the superomedial border and superolateral surface



A2 segment
Third anterior cerebral artery

Fig: 15. Illustration of a third anterior cerebral artery

Fig: 16. Photograph of A2 segment on right and left side with third anterior cerebral artery



Callosomarginal artery arising even before genu
Frontopolar artery arising from the callosomarginal artery

Fig: 17. Variation in Callosomarginal artery

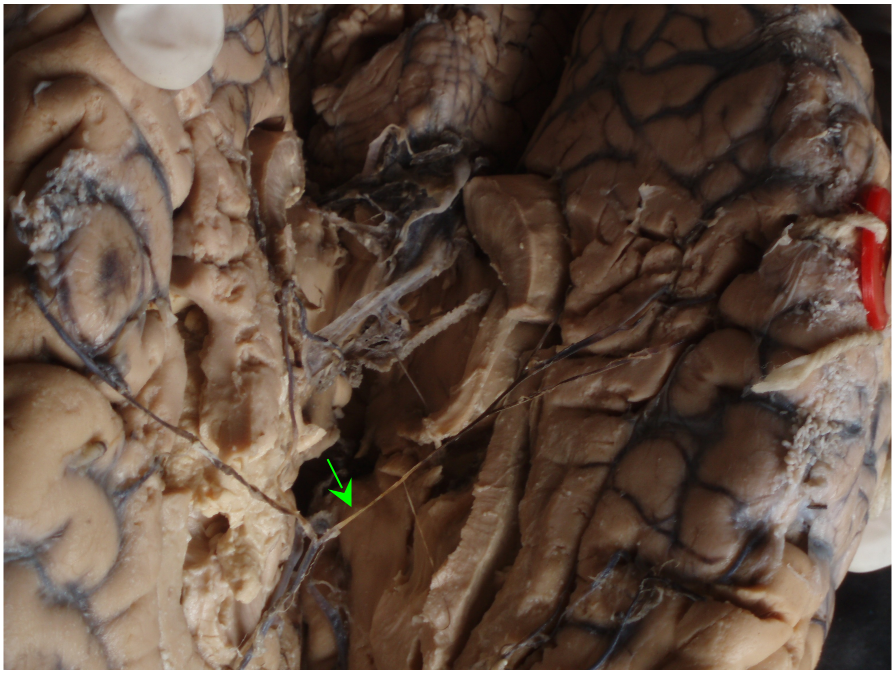


Fig: 18. Image of a left pericallosal artery arising from right A2 segment

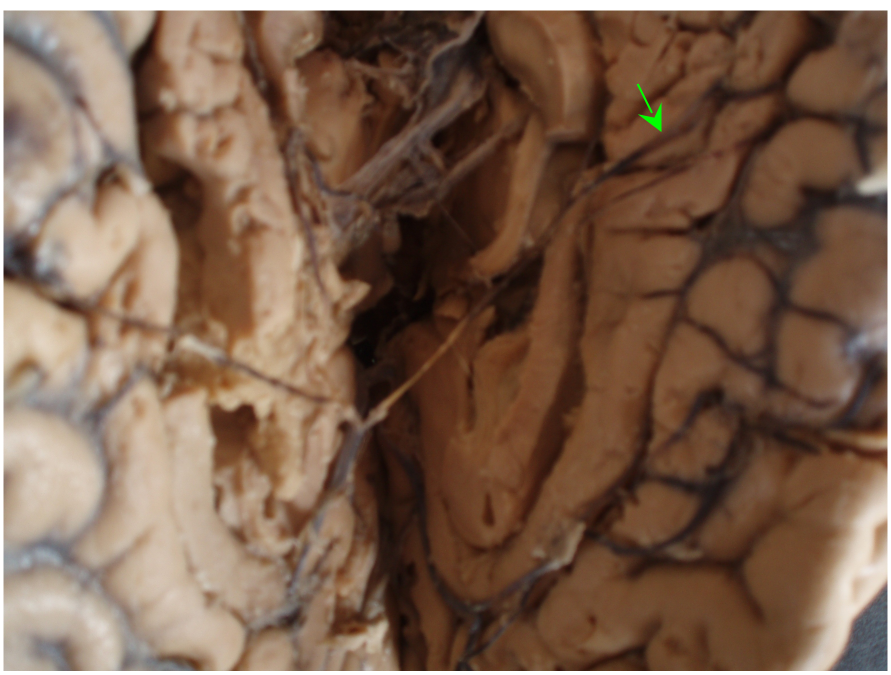


Fig: 19. View of left posterior parietal artery arising from the crossed pericallosal artery

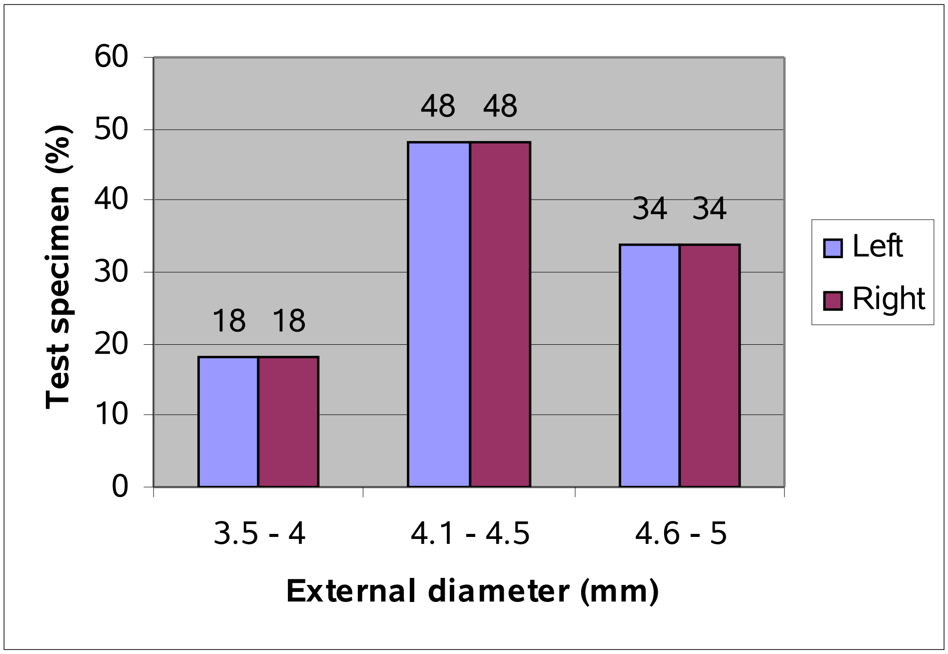


Fig: 20. External diameter of internal carotid artery at its termination

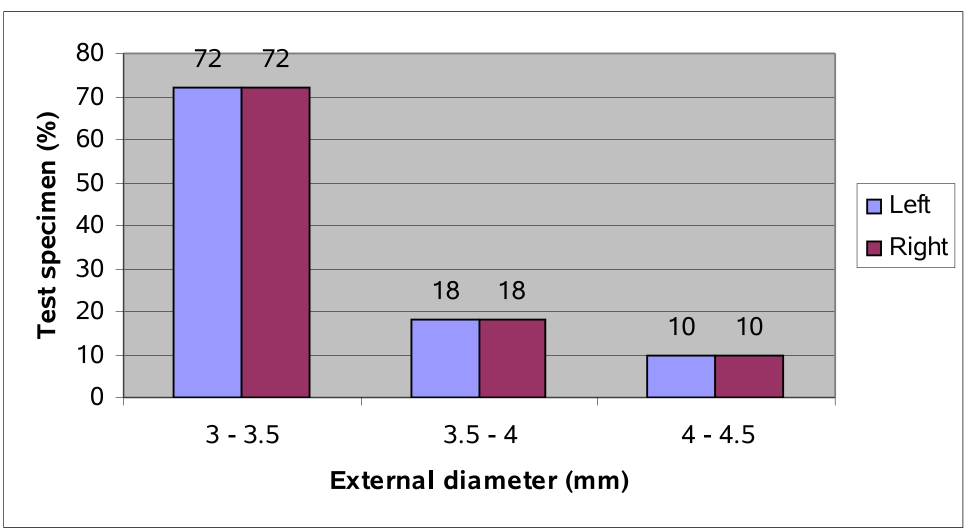


Fig: 21. External diameter of middle cerebral artery at its origin

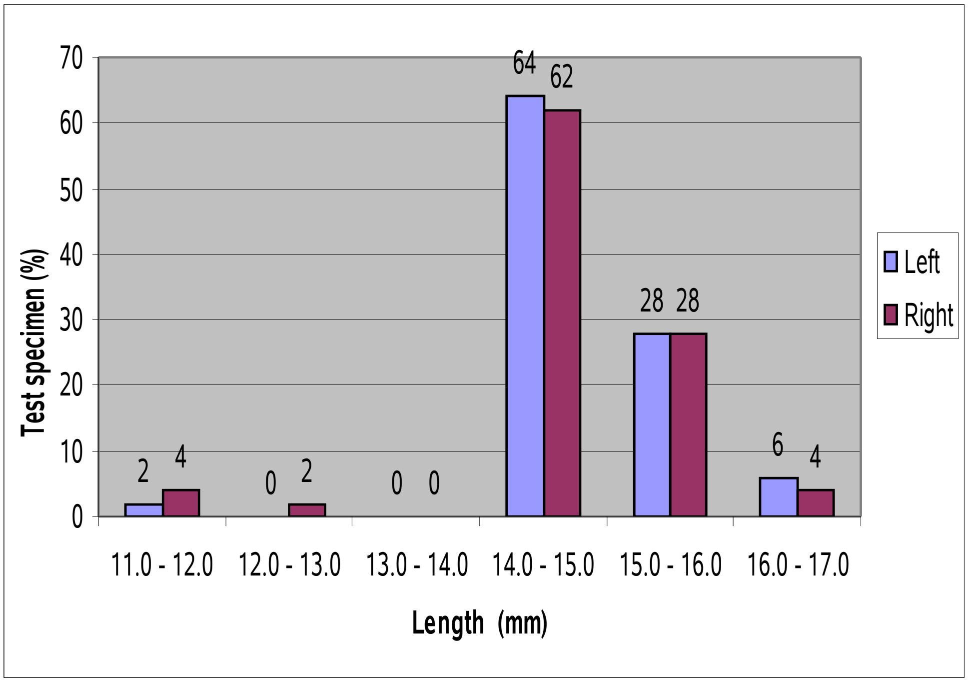


Fig: 22. Length of A1 segment

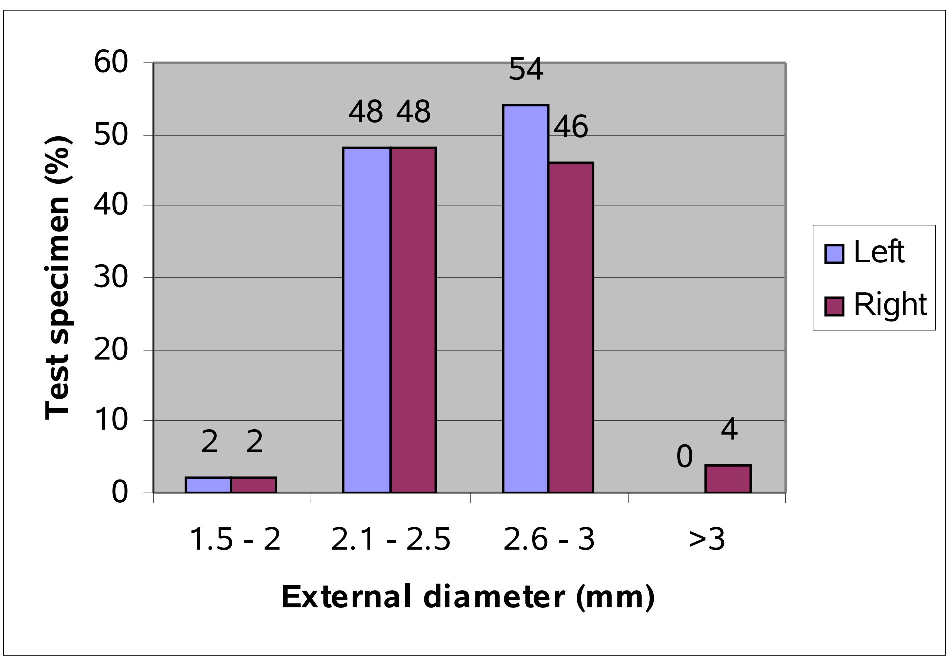


Fig: 23. Outer diameter of A1 segment at its origin

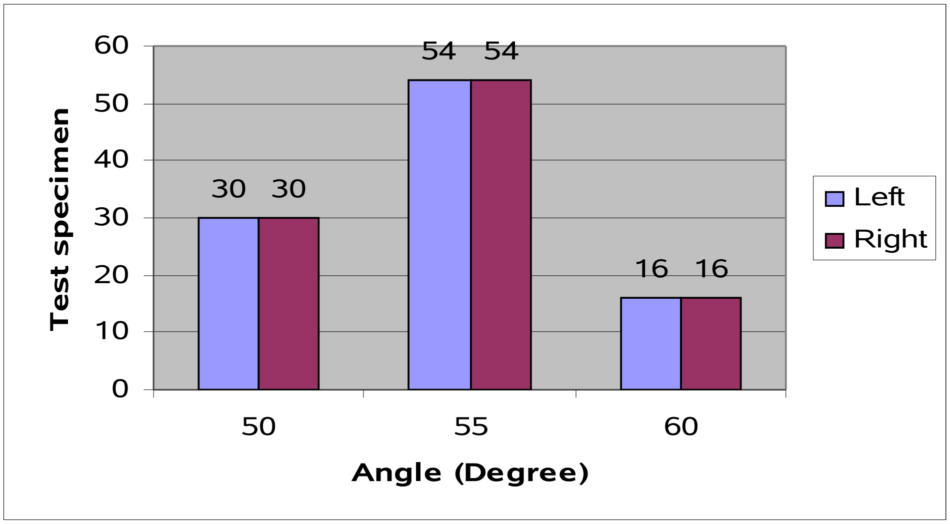


Fig: 24. Angulations of A1 segment

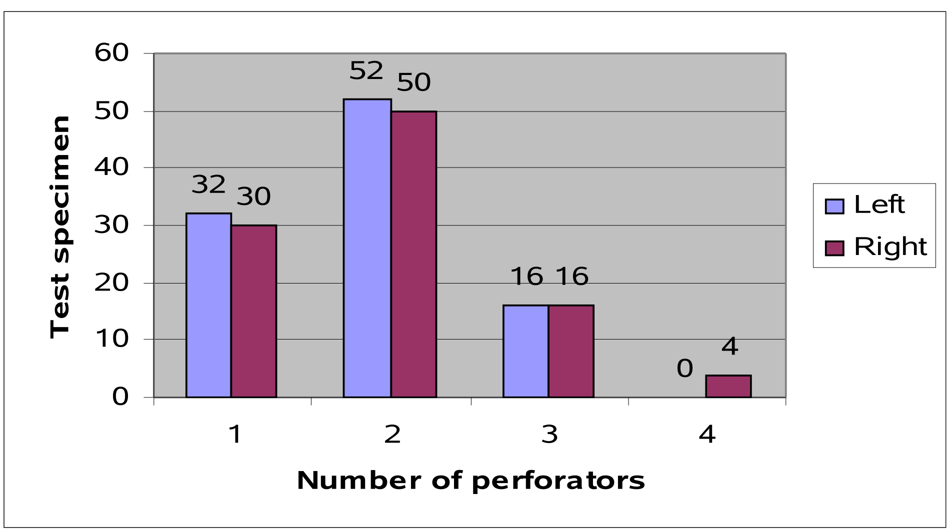


Fig: 25. Branches from A1 segment- perforators

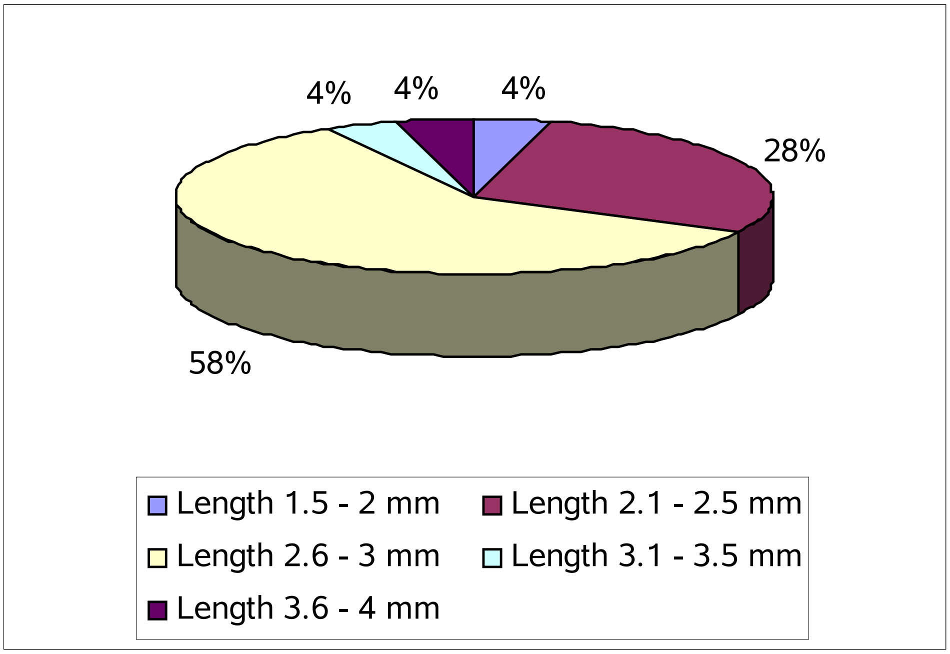


Fig: 26. Percentage variation in the length of Anterior communicating artery

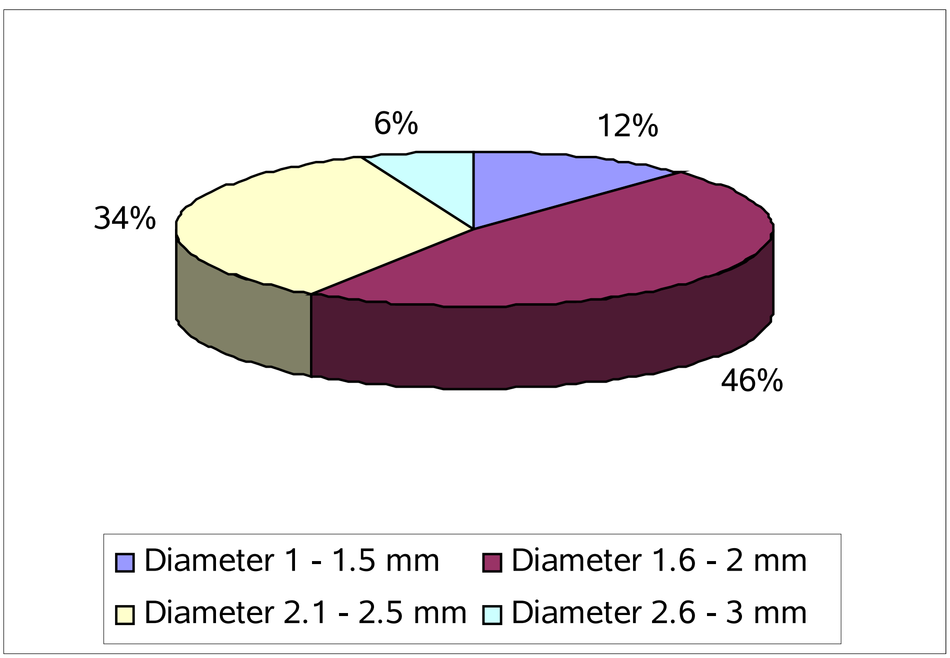


Fig: 27. Percentage variation in the external diameter of Anterior communicating artery

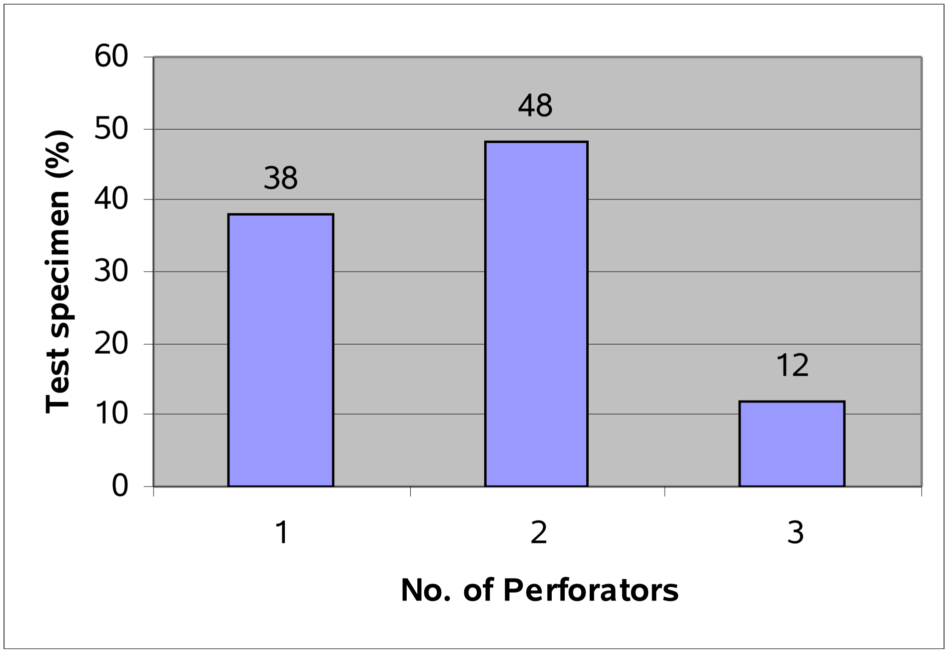


Fig: 28. Anterior communicating artery perforators

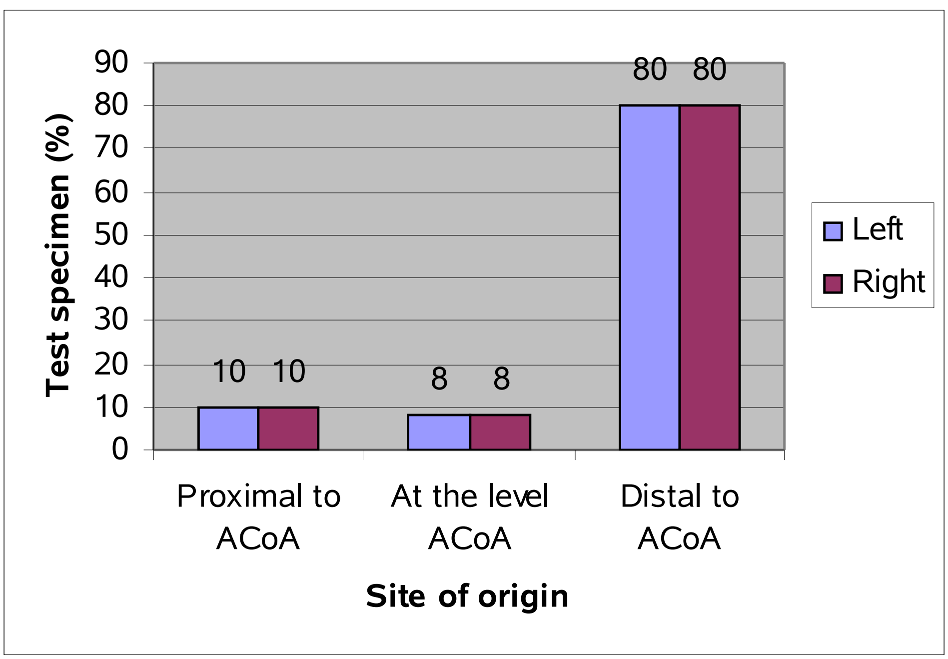


Fig: 29. The Recurrent artery of Heubner

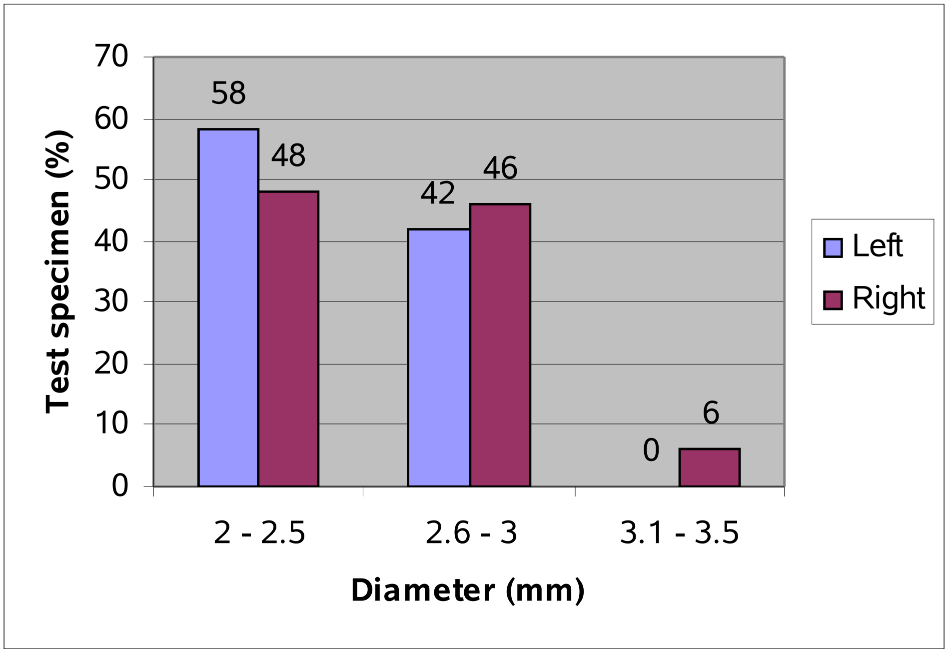


Fig: 30. Diameter of the distal anterior cerebral artery

Fig: 31 (a)

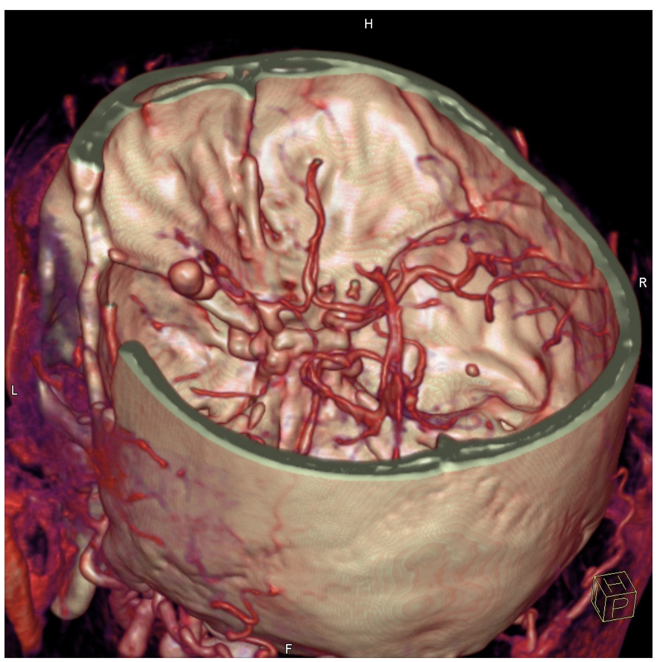


Fig: 31 (b)

Fig: 31. CT angiogram showing arteries forming the circle of Willis

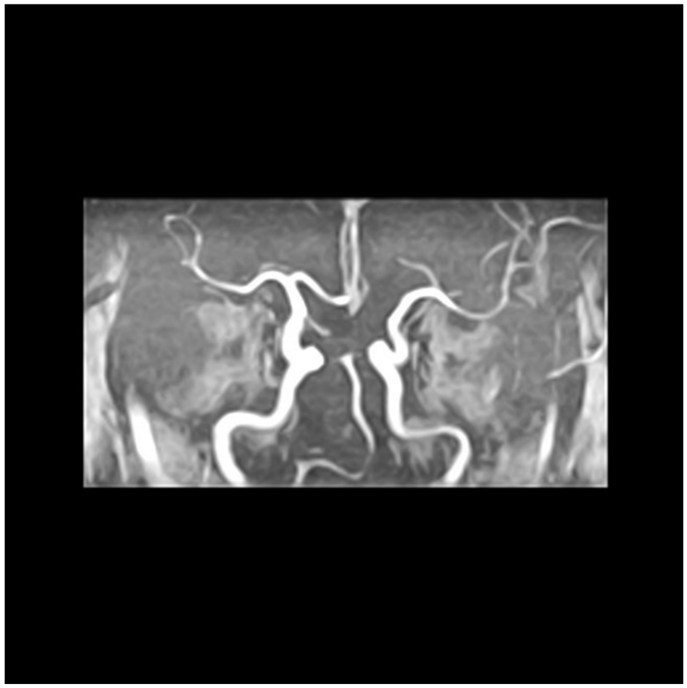


Fig: 32 (a)

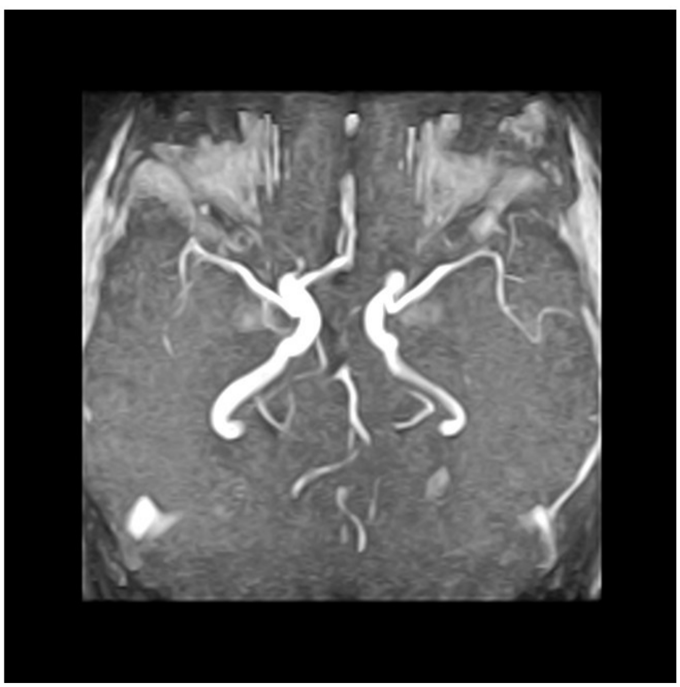


Fig: 32 (b)

Fig: 32. MR angiogram – Axial view showing absence of anterior cerebral artery on one side

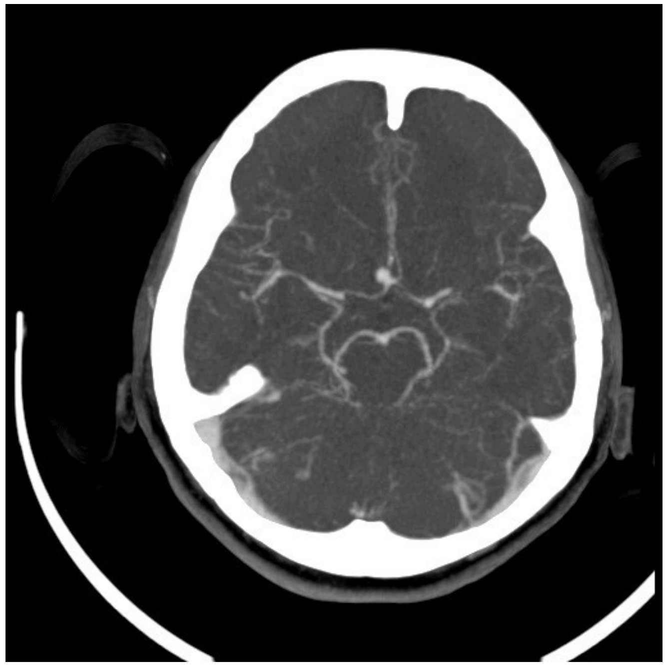


Fig: 33 (a)

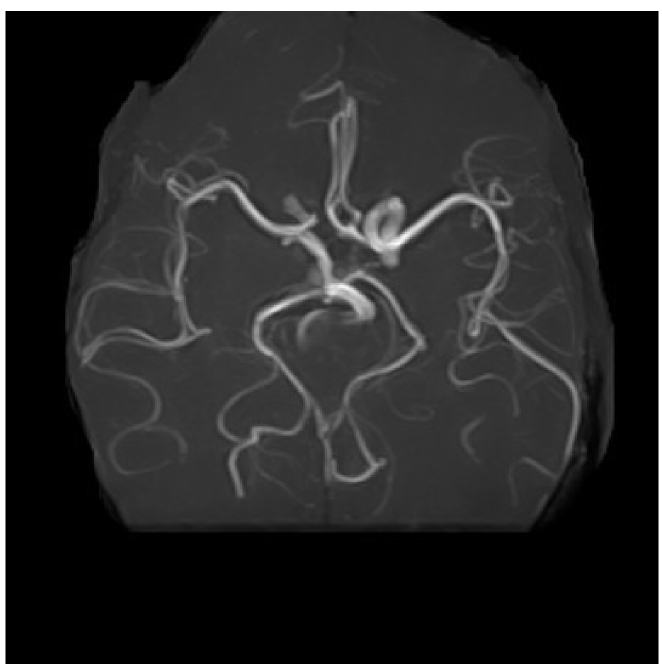


Fig: 33 (b)

Fig: 33. MR angiogram – Coronal view

DISCUSSION

With the advent of advanced techniques in micro neurosurgery and with the evolution of sophisticated diagnostic procedures, cerebrovascular lesions gain much importance in modern days. So a thorough knowledge of the cerebral arteries, its distribution to the cortical functional areas and its distribution through perforative arteries, is of prime importance. In order to add some more to the present details, a study and discussion of the anterior cerebral artery gains significance.

Total of 50 brain specimens were studied irrespective of age, sex and socioeconomic status by gross dissection method. The observations have been recorded, summarized and the data's were classified, analyzed and correlated with the data of previous researches.

Terminal branches of Internal Carotid Artery

In all the specimens studied the anterior cerebral and middle cerebral arteries were the terminal branches of internal carotid artery on both cerebral hemispheres. It is in accordance with the description given in standard text books. It have been noticed that the majority of vessels contributing to the formation of the circulus arteriosus are the anterior cerebral, middle cerebral and posterior cerebral arteries.

Diameter of Internal Carotid Artery at its termination

According to Sylvia Kamath (1980) the diameter of internal carotid artery varied from 3mm to 5mm. S.B Pai et al. (2005) reported the outer diameter of internal carotid artery on both sides ranged from 3.5 to 5mm with a mean of 4.35mm on left and 4.2mm on the right side. In the present study the outer diameter of the internal carotid artery on both sides was in the range of 3.5mm to 5mm with a mean of 4.45mm on left and 4.33mm on the right side.

External diameter of Middle Cerebral artery at its origin

Herman et al. (1963) stated the external diameter of middle cerebral artery at its origin ranged from 3mm to 5mm. In the present study it was from 3.5 to 4mm with a mean of 3.41mm on the right and 3.52mm on the left side.

Origin of the Anterior Cerebral Artery

The internal carotid artery divides into the anterior cerebral and middle cerebral artery at the anterior perforated substance. Standard text books, Gray’s Anatomy and Last’s Anatomy describe the origin of the anterior cerebral artery from the internal carotid artery at the anterior perforated substance. In the present study the site of origin was in accordance with the texts. Regarding the frequency only one artery took origin from each internal carotid artery. It was observed that the anterior cerebral artery contributes for the formation of circle of Wills anterolaterally and courses anteromedially to cross over the optic nerve and optic chiasma to communicate with the opposite anterior cerebral artery through the anterior communicating artery.

External diameter of A1 segment at its Origin

Sylvia Kamath (1980) has stated that, the diameter of right anterior cerebral artery ranged from 1.6mm to 2.8mm, the average being 2.2mm. In the left anterior cerebral artery the range was from 1.9mm to 2.9mm with an average of 2.4mm. As per the observation made by Keele & Neil (1971) the blood flow through shorter and wider vessels were more efficient since the volume of blood flow is inversely related to the length and directly related to the diameter. Hence blood flow will be better in the left half keeping with the dominance of left hemisphere and the common occurrence of right handedness. S.B Pai etal (2005) reported that the outer diameter on both side ranged from 2.5mm to 3.5mm with a mean of 2.9mm on the left and 2.8mm on the right side. As per his observation A1 hypoplasia was much more common when aneurysm was present. Local alterations of intra vascular dynamics might provide the mechanical basis for the development of these aneurysms. According to Brust CM (1986) the diameter ranged from 0.9mm to 4mm with an average of 2.6mm and was more than 1.5mm in 90% of brains. In 74% the diameter was larger than the anterior communicating artery. Perlmutter and Rhoton (1976) used 1.5mm as the cutoff figure for hypoplasia. They found 10% of the brains to have an A1 segment less than 1.5mm in diameter. Alpers BJ,Berry RG & Paddison RM (1959) on their study found string like components in 28% of the A1segment. Riggs & Rupp found A1 hypoplasia of 7% in one of the largest series studied. Puchades-Orts et al 1975 reported on agenesis and hypoplasia of the initial segment of the anterior cerebral artery and anterior communicating arteries resulting in a defective circulation. The present study revealed that the diameter was ranging from 1.5 to 3.5mm with a mean of 2.5mm on the right and 2.6mm on left side. Neither hypoplasia nor agenesis of the arteries was found out.

Length of A1 segment

SB Pai et al (2005) have reported that the length of A1 segment was in the range of 10mm to 19mm with a mean of 14.5mm on the left and 14.6mm on the right side. This segment was noted for hypoplastic changes. In a past study by Slyvia Kamath (1980) the average length of A1 segment was 14.7mm on the right and 13.8mm on the left side. In the present study the range coincides with the study of SB Pai et al.

Angle of origin

It has been noticed that the anterior cerebral artery is directed medially with an angulation above the optic nerve and enters the median longitudinal fissure of the brain towards the anterior communicating artery, to be connected to the corresponding artery of the opposite side. SB Pai et al noted the angulation ranged from 45 to 60 degree and in two cases it was 80 degrees. The angulation in the present study varied from 50 to 60 degrees.

A1 segment perforators

As per the standard description these perforator arteries are divided into two groups, posteroinferior and posterosuperior. Posteroinferior perforators were generally very small twigs and about 2 to3 in number per A1 segment situated more medially than laterally and supplied the optic nerve and optic chiasma. Posterosuperior perforators arose as a large stem divided into smaller branches and penetrated the anterior perforated substance. According to the site of origin A1 segment perforators were divided into proximal, middle and distal as demonstrated by SB Pai et al (2005). On his study a mean of 3 perforators were found in the proximal portion, 1.7 in the middle portion and 1.6 in the distal segment. Barry 1976 reported the origin of perforators was unusual from the initial 5mm of A1. In the present study the perforators were in the range of 1 to 4 in number which mostly arises from the posteroinferior part of the A1 segment.

Anterior Communicating Artery

SB Pai et al (2005) reported that the anterior communicating artery was found in all the ten cases studied and was situated above the optic chaisma in the transverse plane in nine cases but was obliquely placed in one specimen. In the present study the anterior communicating artery was absent in one specimen.

a) Length

W Henry Hollinshead 1961 reported that the length of the anterior communicating artery varied from 1.5mm to 4mm with a mean of 2.6mm. As per Sylvia Kamath (1980) the length varied from 0.9 to 4.3 mm and it showed the greatest variation. Pai SB et al (2005) noticed the length ranging from 1mm to 4mm with a mean of 2.45mm. With reference to text Gray's Anatomy, the anterior communicating artery may be 4mm in length and may be double. The range in the present study varied from 1.5 to 4mm with a mean of 2.6mm.

b) External diameter

As per the study of Sylvia Kamath (1980) the diameter varied from 0.1 to 2.8mm with an average of 1.9mm and also an abnormal diameter was found in two specimens with a diameter less than 0.5mm. The study of Perlmutter D, Rhoton AL (1976) reported that the diameter was in the range of 0.2 to 3.4mm (average 1.5mm). SB Pai et al (2005) observed the diameter from 1mm to 3.5mm with a mean of 2.1mm. Various kinds of duplication, triplication, fenestrations, trabeculations, reticular patterns, loops and bridges were noted by Yasargil (1987) in their series. In the present study the diameter was between 1 & 3mm with a mean of 2mm. Duplication was seen in four of the specimens studied with formation of loop in one specimen and other variations as quoted in the series of Yasargil were not found out.

Segmental duplication also termed fenestration were located at the level of the anterior communicating artery in the form of oviform, triangular, looped or fissured. The occurrence of fenestration was estimated as 16.6% by Radomir R Vucetic (1998). Another study by Ito J et al (1981) quoted the incidence of arterial fenestration as 0.3 to 0.9% angiographically. Several theories for the pathogenesis of fenestration have been proposed. Fenestration may occur as a partial duplication, an incomplete fusion, an anomalous course of a non vascular structure through the precursor vasculature or a remnant anastomosis between the primitive olfactory artery and the anterior cerebral artery. Various authors quoted in their study the incidence of hypoplastic anterior communicating artery. Riggs and Rupp have reported hypoplastic anterior communicating artery as 10%, El Khamlichi et al as 11%, less than 5% by Lazorthes et al and 3% by Fishers. Hypoplasia or aplasia of the anterior communicating artery has not been noticed during the study.

C) Branches – Perforators

With reference to Gray's anatomy numerous anteromedial central branches or perforators arising from the anterior communicating artery provide blood supply to the optic chiasma, lamina termanalis, hypothalamus, para olfactory areas, anterior column of fornix and the cingulated gyrus. Critchley (1930), Grinker (1934) emphatically stated that the anterior communicating artery had no branches. Contrary to this Lewis (1936), Yasirgil (1975) demonstrated the presence of perforators in the anterior communicating artery. Perimutter and Rhoton (1976) reported that the perforators arose from the posterior and superior surface in 90% of the cases. SB Pai et al (2005) observed about 1 to 5 perforators which arose from the posterosuperior surface of the anterior communicating artery and coursed superiorly as a large stem vessel or thin small vessels. In the present study 1 to 3 perforators coursed upwards from the posterosuperior surface.

d) Absence of the anterior communicating artery

Fawcett E (1905) reported the absence of this artery in only one female specimen out of 700 specimens. In the others it was found to be single, double and triple with a percentage of 92.1, 7.2 and 0.1 respectively. W Henry Hollinshead 1961 stated that it was absent when there was fusion between the two anterior cerebral arteries. Windle (1988) on the study with 200 specimens has published in his journal several cases of absence of the artery which were mostly due to fusion of anterior cerebrals. Out of 50 specimen studied in the present series it has been observed that the anterior communicating artery was absent in one specimen and it was due to the fusion of the two anterior cerebral arteries which coincides with the findings of Windle.

Santhoshi et al (2003) explained the absence of fusion of the plexiform anastomosis present in the distal primitive anterior cerebral artery with contralateral A1 hypoplasia. This results in increased haemodynamic stress in the right A1 segment leading to the formation of A1 fenestration and to the subsequent formation of an aneurysm.

The third anterior cerebral artery

It is a third artery originating from the anterior communicating artery in addition to the paired A2 anterior cerebral arteries usually in midline and with branches to one or both hemispheres. This accessory anterior cerebral artery varied in caliber from a small remnant of the median artery of the corpus callosum to a hypoplastic vessel that can resemble an azygos artery when the two A2 anterior cerebral arteries are small in caliber and terminate early.

As per Fawcett E (1905) this artery arose in 3.2% from the anterior communicating artery. In one case the artery arose by two roots, one from each anterior cerebral. In two cases it arose directly from the left anterior cerebral artery and in another case with three anterior communicating arteries, it arose from the middle one. The third anterior cerebral artery which has been described in standard text books was found in only one specimen. The diameter was same as that of the other two A2 segments, followed the same course of A2 segment on left side and ended upwards similar to the callosomarginal branch. Windle (1888) documented the occurrence of the artery as 4.5%. An incidence of 2% was reported in the present study.

Recurrent artery of Heubner

As per SB Pai (2005) the recurrent artery of Heubner was originating either from the A2-anterior communicating artery junction or distal to it. Perlmutter D & Rhotan AL (1976) found the origin of the artery at the A2, A1 and the anterior communicating artery as 78%, 14% and 8% respectively. In the present study 80 % of the artery took origin at the A2 segment, 10% at the anterior communicating portion and 10% from the A1 segment.

Distal anterior cerebral artery or A2 segment

This artery had been further classified into different segments by various authors. But in this study the part of the artery distal to the anterior communicating artery was considered as A2 segment, had diameter ranging from 2mm to 3.5mm with a mean of 2.5mm on both sides as described by SB Pai (2005).

Branches of A2 segment

a) Perforators

No major perforators were noted from the A2 segment as published by SB Pai (2005). Perlmutter D & Rhoton AL (1976) noted an average of 4 perforating branches to the optic chiasma, lamina terminalis and anterior forebrain below the corpus callosum. The present study correlates to the report of SB Pai.

b) Cortical branches

The cortical branches seen constantly during the present study in all the fifty specimens were the orbitofrontal, frontopolar and callosomarginal arteries. The callosomarginal artery was seen to arise from the A2 segment at the genu of the corpus callosum after which the A2 segment continued as the pericallosal artery posteriorly. The A2 segments gave branches to both sides of the hemisphere in 4 cases with an incidence of 8% and were termed bihemispheric. In all this four cases the interhemispheric branches were given off from the right to the left side and so the diameter of the right A2 segment in these specimens were larger than the left side. All this data obtained in the present study correlates with the previous study done by SB Pai, Paul S & Mishra S. They described the anastomoses between the two anterior cerebral arteries with narrowing of one side so that the artery of the opposite side crossed over to compensate for the vascular insufficiency. Aneurysms of the A2 segment can occur all along the course of the artery but was seen commonest at the origin of the callosomarginal artery. Perlmutter D, Rhoton AL (1978) stated that unusual variants may cause aneurysms to develop at other sites by altering the flow dynamics. No such variation was noted in the present study.

S.B. Pai et al (2005) observed in one case that the anterior communicating artery gave rise to the pericallosal artery which coursed directly anterosuperiorly over the genu and then posteriorly over the corpus callosum. No such variations were noted in the present study.

Ferguson (1972) stated that the unusual anatomical variations of the cerebral vessels may cause a flow disturbance leading to aneurysm formation. This assumption was supported by Yasargil (1984) by finding two cases with aneurysm of the unpaired pericallosal artery. Schick RM et al (1989) observed an azygos or unpaired anterior cerebral artery that unites the anterior cerebral artery to form a common link. It was one of the rare anomalies of the cerebral vessels with an incidence of 1.15% in human autopsy cases. No such variation was seen in the present study.

Nicole S Burbank & Pearse Morris (2005) quoted that an anomalous origin of the anterior cerebral artery from the contra lateral internal carotid artery was very rare and they differ in the course while ascending to its normal position. This infra optic course of the A1 segment was associated with agenesis or hypoplasia of the contralateral A1 with a higher prevalence of cerebral aneurysms and arteriovenous malformations. Cerebro vascular ontogenic plasticity theory suggested that altered blood flow dynamics during embryogenesis may account for these coexistent anomalies. The recognition of these anomalies were crucial when planning surgical or endovascular treatment of aneurysms.

Azygos anterior cerebral arteries

Azygos or undivided anterior cerebral artery was a single, midline vessel representing a rare variant of the usually paired A2 vessels. Based on autopsy studies this variant had an incidence ranging between 0.3 and 2% as noticed by Alpers et al (1959).Baptisa AG (1963) distinguished the azygos anterior cerebral arteries from other variants by defining three types of distal anterior cerebral artery anomalies. He referred to the azygos anterior cerebral artery as the "Unpaired anterior cerebral artery" (Type I anomaly). He defined a "Bihemispheric anterior cerebral artery" as an A2 segment of the anterior cerebral artery that sends branches across the mid line to both hemispheres usually in the presence of a contralateral A2 segment that was either hypoplastic or that terminates early in its course towards the genu of the corpus callosum (Type II anomaly). This variant had an incidence of 12%. In the present study no azygos anterior cerebral artery was seen.

SIGNIFICANCE OF THE STUDY

External diameter of internal carotid artery at its termination

In this study the outer diameter of the internal carotid artery was larger on the left when compared to the right side. This shows a better blood flow in the left half of the cerebral hemisphere since the volume of blood flow through a vessel is directly related to its diameter. This fact explains the dominance of the left hemisphere and the common occurrence of right-handedness in human.

External diameter of middle cerebral artery at the origin

The outer diameter of middle cerebral artery at the origin was larger on the left side explaining the fact of more blood supply to the dominant left hemisphere. The outer diameter of middle cerebral artery was larger than the outer diameter of anterior cerebral artery on both sides. This explains that the middle cerebral artery supplies more cortical functional areas than the anterior cerebral artery.

A1 segment perforators

Perforators unusually took origin from the initial 5mm of A1 segment. So placing a clip on the anterior cerebral artery immediately after its origin from the internal carotid artery was usually advised. Posteroinferior perforators to the optic chiasma were very thin and few and may be injured during the retraction causing visual field defects after surgery in this area. The anterior boarder of the A1segment is generally devoid of any perforators and dissection may be carried along this boarder in approaching the anterior communicating artery. The posterosuperior perforators are seen more frequently in the lateral A1 segment than the medial portion. Hence it seems logical that during surgery the temporary clip which is found essential should be placed as medially as possible to avoid perforator ischemia

Anterior communicating artery perforators

Occlusion of these perforators with the aneurysm clip is a major cause of morbidity and mortality in patients with anterior communicating artery aneurysms pointing posteriorly or superiorly. A clear view of the artery was usually hindered by the overhanging gyrus rectus during dissection. The same required to be excised to obtain optimum visualization and space for surgical manipulation in this area.

Embryological correlation to vascular variations

The variations of the anterior circulation of the brain, like any other vascular variations may not have significance in disease, though it is of great importance in the surgery of the region. The vascular anatomy in the region of anterior communicating artery was generally quiet complex due to its embryological development. The intra cranial arteries usually develop in eight stages including the adult configuration. The first seven stages occur during embryogenesis in the first trimester. When the embryo is approximately 40mm in length, (estimated ovulation age 52 days) cerebrovascular development corresponds with the seventh stage of development. At this stage the circle of Willis was recognizable and the stems of all the cerebral arteries attain their adult configuration. In the final embryonic period of cerebrovascular development the vessels branch in accordance with the developing parenchyma. This pattern of development had been termed as cerebrovascular ontogenic plasticity. It was postulated that anomalous arteries and vascular malformations develop during this period due to incomplete fusion of plexiform anastomosis leading to fenestration or doubling or tripling of the anterior communicating artery. The explanation underlying the association between variation and aneurysms were the defects at termination of fusion of the embryonic vessels. The sites of structural wall weakness combined with local hemodynamic forces present particularly at the proximal fenestration and bifurcation predisposed to aneurysm formation.

Recurrent artery of Heubner

It was the first artery seen on retracting the frontal lobe and may get injured while applying the temporary clip or excising the small portion of gyrus rectus leading to hemiparesis. This was because it supplies the anterior limb of the internal capsule, anterior part of the caudate nucleus, anterior third of the putamen, tip of the outer segment of the globus pallidus.

Distal anterior cerebral artery or A2 segment

The space between the two A2 segments was very much less when compared to a larger space available between the two A1 segments. This predisposes A2 segments for occlusion by the aneurysm clip in posteriorly or superiorly directed anterior communicating artery aneurysms.

Cortical branches of A2 segment

The anatomy of the branches of the anterior cerebral artery near the anterior communicating artery complex was investigated to minimize neurovascular morbidity caused by surgical procedures performed in this region. The recurrent artery of Heubner, orbito frontal artery and fronto polar artery were identified as the branches of the anterior cerebral artery arising near the anterior communicating artery complex. The orbito frontal artery always arose from the A2 segment was consistently the smallest branch and coursed to the gyrus rectus, olfactory tract and olfactory bulb. The mean distance between the anterior communicating artery and the orbito frontal artery was 5.96mm. The frontopolar artery arose from the A2 segment and coursed to the medial sub frontal region. The mean distance between the anterior communicating artery and the fronto polar artery was 14.6mm. The recurrent artery of Heubner, orbitofrontal artery and the fronto polar artery were the three branches that arise from the anterior cerebral artery near the anterior communicating artery complex. These vessels had similar diameters but can be distinguished by the final destination. Distinguishing these vessels is important since the consequences of injury or occlusion of the fronto polar artery and orbito frontal artery are significantly less than that of the recurrent artery of Heubner.

The circulus arteriosus offers a potential shunt in abnormal conditions such as occlusions and spasms. In normal circumstances it was not an equalizer and distributor of blood from different sources. There was normally no mixing of the opposing stream of blood which meets in the middle of the anterior communicating arteries at points where the pressure of the two are equal. Anomalies of the artery may play a role in the development of aneurysm by producing hemodynamic changes in blood flow and inducing strain on the weak point of the arteries. The physiological alternation in blood flow may have a prognostic significance in the surgery of aneurysms. In about one third cases, angiographic evidence of defective circulation has been observed. Therefore existence of an effective circulation can never be assumed on surgical procedures involving its feeders and so all surgical interventions of the anterior cerebral artery should be preceded by angiography.

CONCLUSION

The dimensions and branching pattern of the anterior cerebral artery have been studied and the observed result leads to the following conclusions:

1. The anterior cerebral artery took its origin from the corresponding internal carotid artery at the anterior perforated substance and was single in number at its origin. The angulations of the artery towards the anterior communicating artery varied from 50 to 60 degrees in all the specimens.
2. The dimensions corresponding to the external diameter of both the internal carotid artery at its termination and the middle cerebral artery at its origin correlated with the earlier studies.
3. Length and diameter of A1 segment was within the normal limit so that no hypoplastic changes were seen. The perforators arising from this segment were a maximum of 4 in number.
4. The anterior communicating artery was absent in one specimen, doubled in three specimen and a loop like pattern in one specimen. The dimensions of this artery lie within the standard margin. A maximum of three perforators coursed upwards from the posterosuperior surface of this artery.

5. A third anterior cerebral artery was seen to arise from the anterior communicating artery with an incidence of 2%, followed the same course as that of A2 on left side and ended by turning upwards similar to the callosomarginal branch.
6. The recurrent artery of Heubner arose in majority of cases distal to the anterior communicating artery. It has been observed that 80 % of the artery took origin at the A2 segment, 10% at the level of anterior communicating artery and 10% from the A1 segment.
7. Diameter of A2 segment was within normal limit. No hypoplastic or aplastic changes occurred. The three branches constantly seen in the entire specimen are the orbitofrontal, frontopolar and callosomarginal artery. Inter hemispheric branches were also present in four specimens.
8. The majority of the aneurysms of the anterior cerebral artery near the anterior communicating artery pointing anteriorly and inferiorly are safely clippable. The posterior and superiorly pointing aneurysms are fraught with more risks due to the proximity and involvement of anterior communicating artery perforators, recurrent artery of Heubner and A2 segments. Hence the anatomy of the branches arising from the anterior cerebral artery near the anterior communicating artery

complex was to be investigated properly to minimize neurovascular morbidity caused by surgical procedures performed in this region.

9. The present study conform the high percentage of variations in the anterior cerebral artery, to more variations in the anterior communicating artery and distal anterior cerebral artery segments rather than A1 segments. The anterior cerebral artery - anterior communicating artery complex is incredibly varied and consequently the surgery in this area is extremely challenging.

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MASTER CHART – ANTERIOR CEREBRAL ARTERY

S.No	Diameter of ICA (mm)		Diameter of MCA (mm)		Origin of ACA		No. of arteries at the origin (Nos)		Site of origin		A1 Segment								ACoA			A2 Segment	
											Diameter (mm)		Length (mm)		Angle of origin (Degree)		Branches (Nos)					Diameter (mm)	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Length (mm)	Diameter (mm)	Branch (Nos)	Right	Left
1	4.8	4.8	3.5	3.5	ICA	ICA	1	1	APS	APS	2.4	2.6	14.3	14.4	55	55	2	1	2.3	2.2	2	2.3	2.2
2	4.6	4.6	3.2	3.2	ICA	ICA	1	1	APS	APS	2.4	2.4	14.2	14.2	55	55	2	2	2.4	2.2	1	2.2	2.4
3	4.8	4.8	3.4	3.4	ICA	ICA	1	1	APS	APS	2.3	2.4	14.3	14.3	50	50	3	1	2.3	2.2	2	2.5	2.5
4	4.5	4.5	3.1	3.1	ICA	ICA	1	1	APS	APS	2.4	2.4	14.6	14.6	55	55	1	2	2.6	2.4	3	2.4	2.5
5	4.5	4.5	3.1	3.1	ICA	ICA	1	1	APS	APS	2.3	2.3	15.1	15.1	50	50	2	2	3.1	2.3	2	2.5	2.6
6	4.6	4.6	3.2	3.2	ICA	ICA	1	1	APS	APS	2.6	2.6	14.8	14.8	50	50	2	3	2.8	2.3	2	2.3	2.4
7	3.8	4	3.5	3.4	ICA	ICA	1	1	APS	APS	2.3	2.5	14.1	14.3	55	55	3	3	2.8	2.2	2	2.2	2.2
8	4.3	4.4	3.6	3.6	ICA	ICA	1	1	APS	APS	2.8	2.9	15.2	15.3	50	50	1	1	2.9	1.6	1	2.2	2.2
9	4.6	4.6	3.5	3.5	ICA	ICA	1	1	APS	APS	2.6	2.6	14.6	14.7	55	55	4	3	2.6	1.6	2	2.5	2.5
10	4.5	4.5	4.2	4.2	ICA	ICA	1	1	APS	APS	2.8	2.8	15.1	15.1	55	55	3	2	1.5	1.2	2	2.6	2.6
11	4.3	4.4	3.6	3.6	ICA	ICA	1	1	APS	APS	2.7	2.8	14.6	14.7	55	55	2	2	2.8	1.6	2	3	2.1
12	4.4	4.2	3.8	3.8	ICA	ICA	1	1	APS	APS	3	2.1	11.2	16.1	55	55	1	1	4	1.2	1	2.8	2.8
13	4.8	4.8	3.4	3.4	ICA	ICA	1	1	APS	APS	2.9	2.9	14.2	17	60	60	2	2	1.8	1.4	2	2.3	2.4
14	4.6	4.8	3.3	3.4	ICA	ICA	1	1	APS	APS	2.8	3	15.1	15.1	60	60	3	1	3.2	1.8	3	2.4	2.4
15	4.2	4.3	3	3	ICA	ICA	1	1	APS	APS	2.8	2.8	14.8	14.8	55	55	3	2	2.1	1.6	2	2.4	2.5
16	3.5	3.5	3.2	3.3	ICA	ICA	1	1	APS	APS	2.8	2.8	14.5	14.5	50	50	2	1	2.3	1.4	3	2.4	2.5
17	3.4	3.5	3.1	3.1	ICA	ICA	1	1	APS	APS	2.6	2.6	14.1	14.1	55	55	1	3	2.1	1.7	3	3.1	3
18	3.5	3.4	3.1	3.2	ICA	ICA	1	1	APS	APS	2.3	2.3	11.5	11.4	60	60	1	2	3	3	3	2.4	2.5
19	4.3	4.4	3.6	3.7	ICA	ICA	1	1	APS	APS	2.8	2.9	14.8	14.8	50	50	4	1	2.8	1.6	1	2.3	2.3
20	4.3	4.5	4.2	4.2	ICA	ICA	1	1	APS	APS	2.8	2.8	14.4	14.4	55	55	2	2	2.3	1.6	2	2.3	2.3
21	4.2	4.3	3.3	3.3	ICA	ICA	1	1	APS	APS	2.3	2.3	14.3	14.4	55	55	2	2	2.4	1.8	2	2.6	2.5
22	3.3	3.1	3	3	ICA	ICA	1	1	APS	APS	2.2	2.2	16	15.1	55	55	2	2	3	1.6	2	3.1	1.8
23	4.6	4.7	3.8	3.9	ICA	ICA	1	1	APS	APS	3.2	2.7	15.1	15.2	50	50	1	1	2.5	1.6	3	2.4	2.5

24	3.3	3.3	3.1	3.1	ICA	ICA	1	1	APS	APS	2.3	2.3	15.1	14.6	50	50	1	1	2.8	1.4	2	2.6	2.6
25	3.6	3.7	3	3	ICA	ICA	1	1	APS	APS	2.8	2.9	14.6	14.6	50	50	3	3	2.3	1.5	2	2.8	2.8
26	4.8	4.8	4.5	4.6	ICA	ICA	1	1	APS	APS	2.8	2.9	15.2	15.3	60	60	2	2	2.6	1.8	2	2.8	2.6
27	3.5	3.5	3.1	3.1	ICA	ICA	1	1	APS	APS	2.8	2.8	14.6	14.3	60	60	2	3	2.8	1.6	1	2.8	2.8
28	4.6	4.6	4.3	4.3	ICA	ICA	1	1	APS	APS	2.8	2.9	15.2	15.2	60	60	1	2	2.6	1.8	1	2.4	2.5
29	3.5	3.5	3	3	ICA	ICA	1	1	APS	APS	2.5	2.6	15.2	15.2	50	50	1	1	4	2.5	2	2.5	2.6
30	4.3	4.3	3.8	3.8	ICA	ICA	1	1	APS	APS	2.3	2.3	15.3	15.4	55	55	1	1	2.8	2.3	2	2.8	2.7
31	4.6	4.6	3.8	3.8	ICA	ICA	1	1	APS	APS	2.4	2.4	14.8	14.7	55	55	2	1	2.6	1.6	1	2.7	2.6
32	4.8	4.8	3.8	3.8	ICA	ICA	1	1	APS	APS	2.6	2.7	15.3	15.1	55	55	2	2	2.7	1.8	1	2.4	2.5
33	4.6	4.6	3.6	3.6	ICA	ICA	1	1	APS	APS	2.4	2.4	15.4	15.2	50	50	3	1	2.8	2.2	1	2.6	2.5
34	4.6	4.6	3.6	3.6	ICA	ICA	1	1	APS	APS	1.6	1.7	16.4	16.2	50	50	1	3	2.6	2.1	2	2.8	2.7
35	4.3	4.4	3.2	3.2	ICA	ICA	1	1	APS	APS	2.3	2.3	15.4	15.4	55	55	2	2	2.4	1.8	1	3.1	2.4
36	4.4	4.4	3.2	3.2	ICA	ICA	1	1	APS	APS	3.1	2.1	13.2	14.3	60	60	2	2	2.6	2.1	2	2.5	2.6
37	4.6	4.6	3.2	3.2	ICA	ICA	1	1	APS	APS	2.5	2.5	14.3	14.2	55	55	2	2	2.7	2.1	2	2.4	2.4
38	4.5	4.5	3.2	3.2	ICA	ICA	1	1	APS	APS	2.6	2.7	14.6	14.5	55	55	2	2	2.3	1.8	1	2.7	2.6
39	4.5	4.5	3.2	3.2	ICA	ICA	1	1	APS	APS	2.9	2.9	14.8	14.8	55	55	2	1	2.8	2.3	2	2.9	3
40	4.5	4.5	3.2	3.2	ICA	ICA	1	1	APS	APS	2.6	2.6	14.6	14.2	60	60	1	2	2.8	2.1	2	2.6	2.5
41	4.2	4.2	3.2	3.2	ICA	ICA	1	1	APS	APS	2.5	2.5	14.4	14.4	55	55	1	1	2.6	1.8	1	2.5	2.5
42	4.4	4.4	3.2	3.2	ICA	ICA	1	1	APS	APS	2.6	2.7	14.3	14.3	55	55	2	3	3	1.8	1	2.8	2.7
43	4.6	4.6	3.4	3.4	ICA	ICA	1	1	APS	APS	2.5	2.5	14.6	14.5	50	50	3	1	2.7	1.8	2	2.7	2.6
44	4.6	4.6	3.3	3.3	ICA	ICA	1	1	APS	APS	2.4	2.5	14.3	14.3	50	50	2	2	1.3	1.8	1	2.6	2.6
45	4.5	4.5	3.3	3.3	ICA	ICA	1	1	APS	APS	2.5	2.5	14.6	14.5	55	55	1	2	2.2	2.1	1	2.5	2.4
46	4.8	4.8	3.5	3.5	ICA	ICA	1	1	APS	APS	2.5	2.6	14.3	14.3	50	50	1	2	2.6	1.8	1	2.5	2.5
47	4.5	4.5	3.2	3.2	ICA	ICA	1	1	APS	APS	2.5	2.5	14.5	14.3	55	55	2	2	3.5	3	1	2.7	2.6
48	4.5	4.5	3.3	3.3	ICA	ICA	1	1	APS	APS	2.6	2.6	14.6	14.5	55	55	2	2	2.8	2.2	1	2.7	2.6
49	4.5	4.5	3.3	3.3	ICA	ICA	1	1	APS	APS	2.5	2.6	14.6	14.5	55	55	2	2	2.8	2.2	1	2.6	2.5
50	4.5	4.5	3.4	3.4	ICA	ICA	1	1	APS	APS	2.5	2.6	14.6	14.5	55	55	2	2	2.9	2.1	1	2.6	2.5

ACA – Anterior Cerebral Artery
ACoA – Anterior Communicating Artery
APS – Anterior Perforated Subtance
ICA – Internal Carotid Artery
MCA – Middle Cerebral Artery